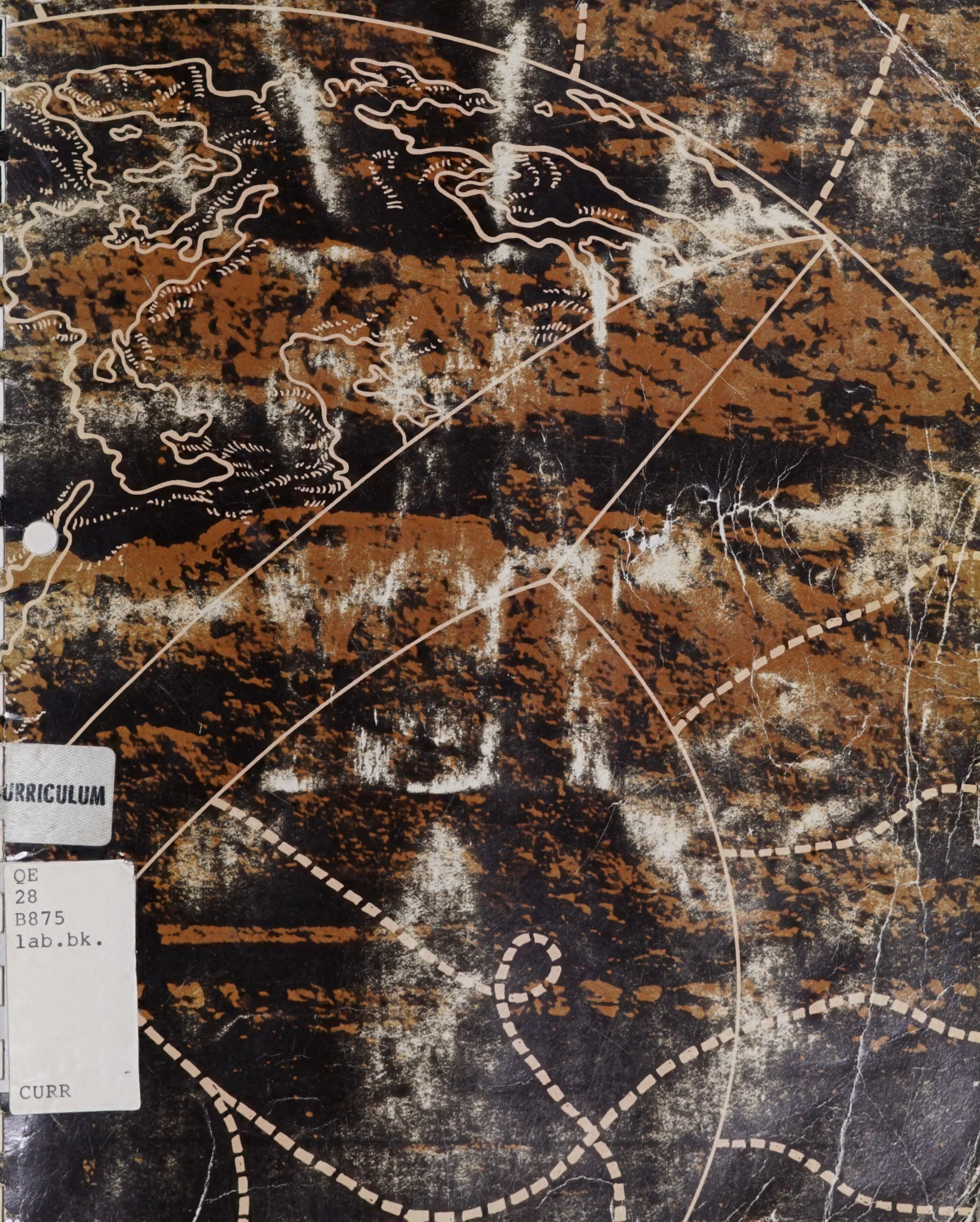
Laboratory Investigations in

EARTH SCIENCE



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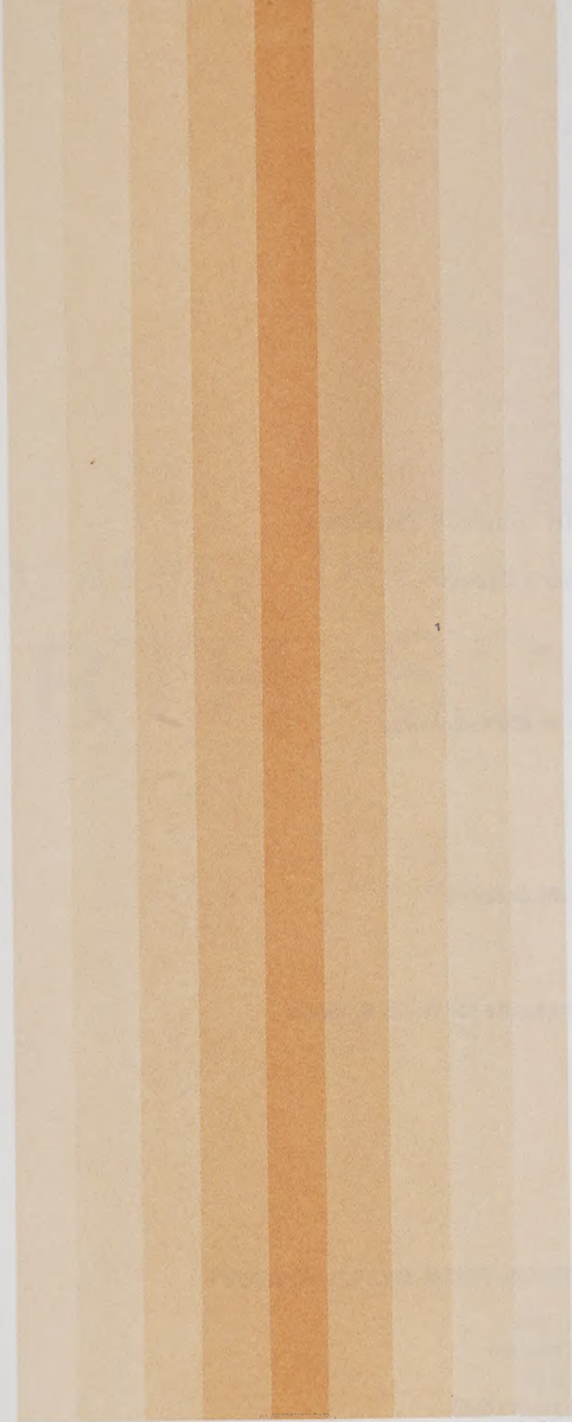

Laboratory Investigations in
EARTH SCIENCE

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Laboratory Investigations in EARTH SCIENCE

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NAME______________________________ SECTION__________ DATE______________

INVESTIGATION 1-1

Measurement

Aim: To compare the English system of measurement with the metric system and to determine the relative ease of using each system

MATERIALS

Metric ruler
English unit ruler
Stiff paper cards
Watch

Step A Using the English unit ruler, make the following measurements. Be accurate to the nearest 1/16 inch and time yourself.

TABLES OF LINEAR MEASUREMENT

English system	Metric system
1 foot (ft) = 12 inches (in)	1 centimeter (cm) = 10 millimeters (mm)
1 yard (yd) = 3 feet	1 meter (m) = 100 centimeters
1 mile (mi) = 5,280 feet	1 kilometer (km) = 1,000 meters

1. Record the time at the beginning of Step A.

______hr ______min

2. Measure the length of the card. ______in

3. Measure the width of the card. ______in

4. Calculate the area of the card. ______in^2

5. Record the time at the end of Step A.

______hr ______min

6. How long did it take you to do Step A?

______min

Step B Repeat Step A, using the metric ruler. Be accurate to the nearest millimeter.

7. Record the time at the beginning of Step B.

______hr ______min

8. What is the length of the card? ______mm

9. What is the width of the card? ______mm

10. What is the area of the card? ______mm²

11. Record the time at the end of Step B.

______hr ______min

12. How long did it take to do Step B? ______min

13. Which step, A or B, did you complete more rapidly?

Step______

14. Why did the work in that step take less time?

______

______

______

Step C Changing from one unit to another is more cumbersome in the English system than in the metric system. Prove this to yourself by converting the area of the card to the fraction (or decimal) of a square foot and also the fraction (or decimal) of a square meter.

15. What was the area of the card in square inches (A-4)?

______in²

16. How many square inches are there in a square foot?

______in²

17. Divide the area of the card in square inches by the area of a square foot in square inches, and you will have the area in square feet. What is it?

______ft²

18. What is the area of the card in square millimeters?

______________mm^2

19. How many millimeters are there in a meter?

______________mm

20. How many square millimeters are there in a square meter?

______________mm^2

21. Divide the area of the card in square millimeters by the area of a square meter in square millimeters and you will have the area in square meters. What is it?

______________m^2

22. Which was the easier calculation, C-17 or C-21?

____

23. Why was this so?

____

____

____

24. What is one good reason why scientists use the metric system?

____

____

Step D You have been using the English system of linear measurement all your life. Therefore, you are familiar with measurements in inches, feet, and miles. Because of this we have included that system in the textbook. However, you should have some idea about the relationship between English and metric distances. Officially, 1 meter is the same as 3.280833 feet. In converting meters to feet and feet to meters, little error will occur if you use the conversion 1 meter = 3.28 feet.

25. How many inches are there in a meter?

______________in

26. How many centimeters are there in an inch?

______________ cm

27. How many meters are there in a kilometer?

______________ m

28. How many feet are there in a kilometer?

______________ ft

29. How many feet are there in a mile?

______________ ft

30. What decimal part of a mile is 1 kilometer?

______________ mi

31. What simple fraction is nearest to this part of a mile?

____

Here are some handy tables of equivalents in the English and metric systems. There is no need to memorize these tables if you can remember where to find them when you need them.

ENGLISH SYSTEM TO METRIC SYSTEM	
Area	$1\ \text{in}^2 = 6.452\ \text{cm}^2$
	$1\ \text{ft}^2 = 0.09290\ \text{m}^2$
Capacity (fluids)	1 qt = 0.94633 l
Volume	$1\ \text{in}^3 = 16.3872\ \text{cm}^3$
	$1\ \text{ft}^3 = 0.2832\ \text{m}^3$
Weight	1 lb = 0.45359 kg-wt

METRIC SYSTEM TO ENGLISH SYSTEM	
Area	$1\ \text{cm}^2 = 0.1550\ \text{in}^2$
	$1\ \text{m}^2 = 10.764\ \text{ft}^2$
Capacity (fluids)	1 l = 1.0567 qt
Volume	$1\ \text{cm}^3 = 0.0610\ \text{in}^3$
	$1\ \text{m}^3 = 35.314\ \text{ft}^3$
Weight	1 kg = 2.2046 lb

NAME ______________________ SECTION ________ DATE ________

INVESTIGATION 2-1

Orbiting Masses

Aim: To discover the relationship between radius and velocity in an orbit

MATERIALS

¼-inch glass tubing, fire-filed (6″ long)
Nylon fishline, about 14-pound strength (48″ long)
⅜-inch hexagonal nuts (8)
Meterstick
Stopwatch or watch with second hand

Step A Assemble the apparatus as shown in Figure 1:

(1) Thread the line through the piece of glass tubing. (2) Tie 1 mass (nut) to one end of the line; be sure that the knot is secure. (3) Tie 7 masses (nuts) to the other end of the line; be sure that the knot is secure.

To test the apparatus, stand well away from your nearest neighbor. Hold the glass tube vertically in one hand so that the end of the line with 1 mass attached is uppermost. Now, with a slight rotary motion of the hand holding the tube, get the mass into orbit.

1. As the mass goes into orbit, what happens to the radius of the orbit as represented by the length of line between the mass and the glass tube?

____

____

____

____

2. What happens to the position of the masses hanging below the glass tube?

____

____

____

____

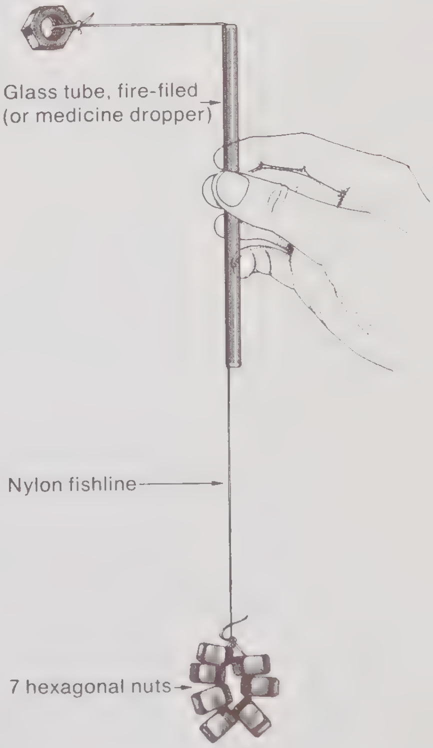

Figure 1

3. What force is holding the single mass in orbit?

4. What weight is equivalent to that force?

5. What causes the weight?

Step B Repeat the experiment three times, producing orbits that differ in radius.

6. As you changed the radius of the orbit, did you alter the force holding the mass in orbit? Explain your answer.

7. As you changed the radius of the orbit, what happened to the velocity of the mass in orbit?

Step C Design and carry out an experiment to measure the velocity of the mass in orbit. Perform this experiment with two different radii. To arrive at a good estimate of velocity, time 10 orbits with a stopwatch. Using these results and the radius of the orbit, you can establish a method for estimating the velocity along the orbit in cm/sec.

8. What were the radius and the velocity involved in the first set of measurements?

Radius ________________cm

Velocity ________________cm

9. What were the radius and the velocity involved in the second set of measurements?

Radius ________________cm

Velocity ________________cm

10. Did this step confirm what you had estimated in **B-7**?

____

____

____

____

Step D The force that holds a mass in orbit can be calculated from the equation $f = \frac{mv^2}{r}$.

11. In the experiments you performed in Step C, what changes occurred in f?

____

12. In the same experiments, what changes occurred in m?

____

13. What happened to v as r increased?

____

Step E In Step D you demonstrated that for any specific orbiting body, $\frac{v^2}{r}$ is a constant.

14. What values for $\frac{v^2}{r}$ did you find in your two experiments in Step C?

Trial 1 ____________cm/sec^2

Trial 2 ____________cm/sec^2

15. Theoretically, the values in 1 and 2 should be equal. Why are they not equal?

16. How could you change the way you performed the experiment in order to reduce the experimental error?

NAME ____________________ SECTION ________ DATE ____________

INVESTIGATION 3-1

Apparent Retrograde Motion

Aim: To demonstrate the cause of apparent retrograde motion

MATERIALS

Hard pencil
Straightedge or ruler

Step A In this exercise you will test the hypothesis which states that the apparent retrograde motion of a planet is caused by the earth's overtaking and passing the planet as the two revolve around the sun in different orbits.

Figure 1 has been drawn to scale with one exception: The background of stars against which we observe the motion of planets should have been drawn hundreds of feet beyond where it is placed at the top of the page. The orbits of Earth and Mars are represented by arcs at the bottom of the page. In the scale to which they are drawn, ¼ inch is equivalent to 10 million miles.

Look at the data in the following table.

ITEM	Earth	Mars
Radius of orbit, in million miles	94	142
Period of revolution, in earth days	365	687
Circumference of orbit, in million miles	295	445

1. Using this data, calculate in inches the radii of the orbits shown in Figure 1. Make the calculations to the scale noted above (¼ inch = 10 million miles).

Earth ____________________ in

Mars ____________________ in

2. Calculate the distance along their orbit that Earth and Mars each travel in one earth day.

Earth ____________________ million mi

Mars ____________________ million mi

Orbit of Earth

3. Explain why one of the planets travels slower than the other.

4. In Figure 1, the distance between the equally spaced marks on the orbits for Earth are 0.25 inch apart. The marks on the Mars orbit represent the same passages of time. Using the data you found in **A-2**, calculate the distance from one mark to the other on the diagram of the Mars orbit.

Approximately ________ in

Step B Use a well-sharpened 3H pencil and a good straightedge or ruler for this work. Place the straightedge as accurately as you can to draw a line through the marks labeled 1 on the orbits of Earth and Mars. Draw this line to the lowest of the three closely spaced lines at the top of the page. Label the point of intersection 1. Repeat this operation with the points marked 2. The mark for point 2 on the lines at the top of the page lies to the left of the mark for point 1. Any apparent motion in this direction we will call *prograde motion*.

Continue to align your straightedge on points with the same number along the orbits of Earth and Mars. Instead of drawing lines, put a point on the lowest line at the top of the page. As soon as the point you have just made lies to the *right* of the last one you made, apparent retrograde motion has begun. Place all points for retrograde motion on the middle line of the three lines at the top of the page.

Continue plotting the retrograde motion on the middle line until it reverses and becomes prograde again. Be sure to number the points you make at the top of the page.

5. At what point did you last plot prograde motion before retrograde motion began?

Point ______________

6. At what point did retrograde motion cease?

Point ______________

7. Why is *apparent* retrograde motion the proper name for the observed motion of Mars?

8. It takes 12.36 days for Earth to move from one point to the next in its orbit, as shown in Figure 1. For approximately how many days is Mars in apparent retrograde motion?

Approximately ____________ days

NAME______________________________ SECTION__________ DATE__________

Density of a Solid

Aim: To determine the density of a solid

Definition: Density is the mass of a unit volume of a substance. Density of a solid is usually stated as the mass, in grams, of an amount that is 1 cm^3 in volume.

MATERIALS

Balance and weights, or spring scale
Graduated cylinder
Beaker of water
Thread
Piece of stone

Step A To determine the density of a solid, divide its mass in grams by its volume in cubic centimeters. Examine your sample to see how this may be done.

1. How can you estimate the mass of your sample?

____

____

____

2. Determine the mass of your sample.

____

____

3. How do you determine the volume of an object such as a box?

____

____

4. Can you apply this method to your sample?

____

____

____

5. Why?

____

____

Step B In this step you will learn how to determine the volume of an object that is irregular in shape. Look at the apparatus that you have.

6. Is there any piece of apparatus that can be used to measure volume? If there is, what is it?

____

____

7. How would you use this to estimate the volume of the object?

____

____

____

____

____

____

8. Carry out the method you described in **B-7**. What is the volume of the water alone?

__________ml

What is the volume of the water plus the object?

__________ml

What is the volume of the object?

__________ml

9. What is the volume of 1 ml? __________cm^3

10. What is the volume of the object in cm^3?

__________cm^3

Step C From the data that you have accumulated, make a first approximation of the density of the sample object.

11. What is the mass (**A-2**)? ________________g

What is the volume (**B-10**)? ________________cm³

What is the density? ________________g/cm³

12. How accurately did you measure the mass of the sample object: to the nearest g, to the nearest 0.1 g, or to the nearest 0.01 g?

To the nearest ________________g

13. How accurately did you measure the volume of the sample object: to the nearest ml, to the nearest 5 ml, or to the nearest 0.5 ml?

To the nearest ________________ml

14. Why was your first approximation of the density not an accurate estimate?

____

____

To make an accurate estimate of the density of the object, you will have to do another investigation. In the next investigation you will use a method suggested by an ancient Greek philosopher, Archimedes. The principle that he discovered is essentially this: An object submerged in water is buoyed up by a force that is equal to the mass of the fluid the object displaces.

NAME____ SECTION__________ DATE__________

INVESTIGATION 3-3

Archimedes Principle

Aim: To determine the density of an object by using Archimedes' principle

MATERIALS
Balance and weights Beaker of water Cork Thread Piece of stone

Step A If you have not done so, read the paragraph at the end of Investigation 3-2. Then assemble the apparatus as shown in Figure 1 and place the cork in the beaker of water.

1. In what direction does the force of gravity pull an object?

____

2. When we weigh an object, what are we really measuring?

____

____

3. When you hold a cork under water and then let it go, what happens?

____

____

4. What force causes this to happen?

____

____

5. In what direction does this force act?

____

6. Why does the cork float? Give your answer in terms of forces acting upon the cork.

____

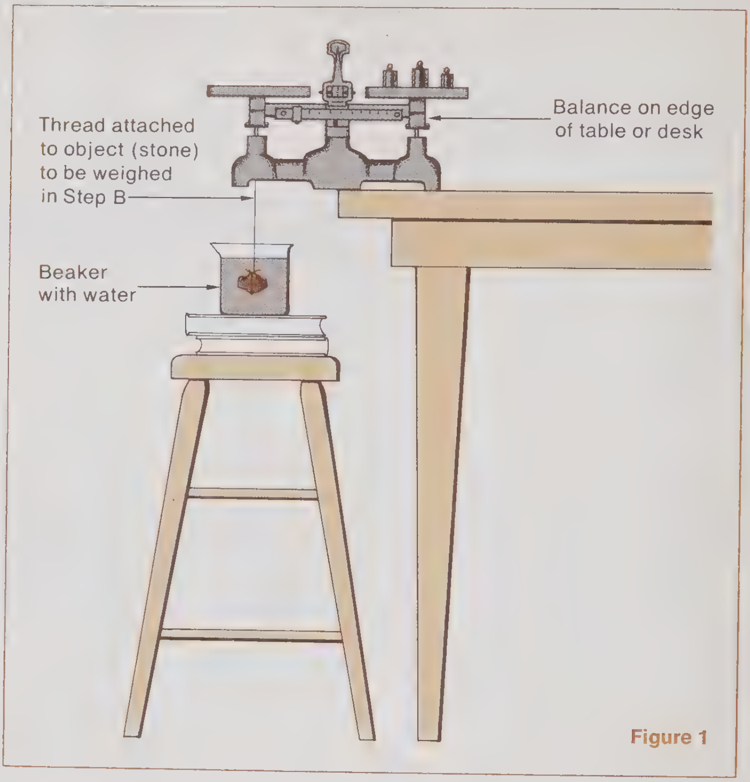
Thread attached to object (stone) to be weighed in Step B
Balance on edge of table or desk
Beaker with water

Figure 1

7. Does the cork float on the surface of the water, or is part of the cork submerged in water?

8. If the force of gravity were greater than the force of buoyancy, would the cork float, or sink?

9. If the force of buoyancy *acting upon the floating cork* were greater than the force of gravity, what would happen?

10. Does this happen? ______________

11. Since the cork is floating, the forces of buoyancy and gravity acting upon the cork are *exactly* the same. Under these conditions, does the cork displace any water? Why?

12. Recalling Archimedes' principle, what mass of water is displaced by the floating cork?

13. Under the conditions of this experiment, the forces of gravity and buoyancy are exactly equal. The cork no longer has any weight, but its mass is unchanged. How much weight has the cork lost?

Step B In Step A you came to the conclusion that a mass in water loses an amount of weight that is exactly equal to the mass of water it displaces. Attach one end of a piece of thread to the center of the underside of the left balance pan. Be sure to use the left-hand pan. Attach the object to the other end of the thread. Weigh the object by balancing it with weights placed on the right-hand pan and by using the slide. The apparatus for Steps A and B is shown in Figure 1.

14. What total weight balances the weight of the object?

______________g-wt

15. Since you used a balance, gravity acted equally upon the object and the weights. Therefore, the mass of the object

is the same number of grams as its gram-weight. What is the mass of the object?

_______________g

Step C Now move a beaker of water under and up on the suspended object so that the object is completely submerged but does not touch the beaker at any place.

16. Reweigh the object in water. What does it weigh now?

_______________g-wt

17. How much weight has the object lost? (**B-14** minus **C-16**)

_______________g-wt

18. The weight was lost because of buoyancy. What was the gram-weight equivalent of the force of buoyancy?

_______________g-wt

19. What gram-weight of water is displaced?

_______________g-wt

20. We can consider that 1 g-wt of water has a mass of 1 g. What was the mass of the water displaced?

The same mass as in **C-17** _______________g

21. What volume is occupied by the mass of water displaced?

_______________cm^3

22. The water was displaced by the object. What is the volume of the object?

_______________cm^3

Step D To compute the density of the object, remember that $d = \frac{m}{v}$.

23. What is the mass of the object (**B-15**)

_______________g

What is the volume of the object (**C-22**)

_______________cm^3

What is the density of the object? _______________g/cm^3

NAME______________________________ SECTION__________ DATE__________

INVESTIGATION 3-4

Density of a Liquid

Aim: To determine the density of a liquid in g/cm^3

MATERIALS

- Balance and weights
- Graduated cylinder
- Beaker of fresh water, preferably distilled
- Beaker of salt solution
- Thread
- Piece of material heavier than water
- Paper towel

Step A The most obvious way to determine the density of a liquid is to weigh a carefully measured volume and then divide the mass (in grams) by the volume (in cm^3).

1. Carefully weigh an empty, dry graduated cylinder. What is the weight to the nearest 0.1 g?

______________g-wt

Step B Pour enough salt water into the cylinder to fill it nearly to the top of the graduations.

2. Read the volume of the salt water you have poured into the cylinder. Read the *bottom* of the curved surface of the liquid. What is the volume to the nearest 0.5 ml?

______________ml

3. Weigh the cylinder and the solution it contains. What is the weight to the nearest 0.1 g?

______________g-wt

Step C You now have enough data to make a first approximation of the density of the salt water.

4. From the data you accumulated in Steps A and B, determine the weight of the solution by making the calculations indicated below:

Weight of cylinder and solution (**B-3**) ______________g-wt

Weight of cylinder (**A-1**) ______________g-wt

Weight of solution ____________g-wt

5. What is the mass of the solution? ____________g

6. What is the volume of the solution (**B-2**)?

____________cm^3

7. What equation is used for determining density?

____

____

8. What is the density of the solution? ____________g/cm^3

Step D A more accurate way of determining the density of a liquid is to compare the loss in weight of an object weighed in pure or distilled water with its loss when it is weighed in the liquid. To do this, use a procedure similar to that used in Investigation 3-3. Follow the instructions given in Step B of that investigation.

9. What is the weight of the object in air?

____________g-wt

10. What is the weight of the object in pure water?

____________g-wt

11. What is the loss of weight? ____________g-wt

Step E Carefully dry the object. Now weigh it in the salt solution.

12. Why was it necessary to dry the object before weighing it in the salt solution?

____

____

____

____

13. What is the weight of the object in the salt solution?

____________g-wt

14. What was the loss of weight? ____________g-wt

Step F You now have the data necessary to determine the density of the solution by comparing the masses of equal volumes of pure and salt water.

15. Archimedes' principle states that an object submerged in a liquid loses an amount of weight equal to the weight of the liquid displaced. What weight of salt solution was displaced? (Estimate this from **E-14**.)

____________g-wt

16. The object displaced its own volume of both pure water and salt water. Therefore, the weight losses in pure water and salt water apply to identical volumes. From the two weight losses and the knowledge that the density of pure water is 1 g/cm^3, you can calculate the density of the salt solution. The equation for this is:

$$\frac{\text{Weight loss in pure water (a)}}{\text{Weight loss in salt water (c)}} = \frac{\text{Density of pure water (b)}}{\text{Density of salt water (d)}}$$

The values for (a), (b), and (c) are known; only (d) is unknown. You can transform the equation to $(d) = \frac{(b) \times (c)}{(a)}$. Substitute in this equation the experimental values you observed, and do the mathematics to obtain (d), the density of the salt solution. What is its density?

____________g/cm^3

NAME ______________________ SECTION ________ DATE ________

Evaporation

Aim: To discover what happens when salt water is evaporated

MATERIALS

- Salt
- Evaporating dish
- Glass stirring rod
- Bunsen burner
- Tripod
- Asbestos mat
- Beaker
- Test tube
- Cold water

Step A Put ¼ teaspoon of ordinary table salt into an evaporating dish and add ½ test tube of water. Stir with a glass rod.

1. What happens to the salt when it is stirred in fresh water?

2. Can you see any salt in the water?

3. What happened to the rest of the salt?

4. Taste the solution by removing a drop with the stirring rod and transferring it to your tongue. Was there any salt in that drop? How do you know?

Step 8 Place the container of salty water on an asbestos mat on the tripod. Light the Bunsen burner and place it under the tripod, as shown in Figure 1. Bring the water to a boil. Hold a test tube half filled with cold water about 4 inches above the boiling water.

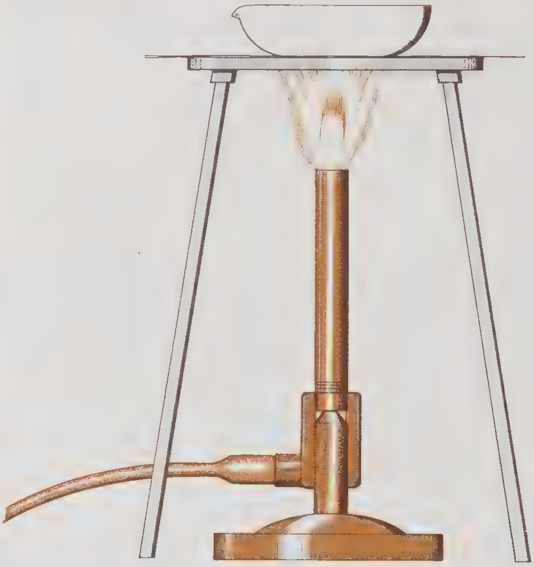

Figure 1

5. What happens to the outer surface of the test tube of cold water?

____

____

____

6. How did these drops form?

____

7. With a freshly rinsed and dried stirring rod, remove a drop of water from the *outer surface* of the test tube. Taste it. What have you learned?

____

____

____

Step C Evaporate the salt solution to dryness by continuing to boil off water.

8. Taste the residue in the evaporating dish. How does it taste?

9. How can fresh water be prepared from salty water?

10. River water rarely tastes salty. Ocean water is very salty. How do you suppose the salt accumulated in the ocean?

NAME________________________________ SECTION__________ DATE__________

INVESTIGATION 4-1

Producing a Metal from One of Its Ores

Aim: To produce a metal from one of its ores

MATERIALS

- Small fragment of galena
- Charcoal block
- Blowpipe
- Bunsen burner

Step A Galena is an ore of lead. Examine the small piece that you have been given.

1. What is the color of galena? ______________

2. Is galena dull, or shiny? ______________

3. The piece of galena that you have was broken from a larger piece. Does galena appear to break irregularly, or in such a way as to produce small, definite flat faces at definite angles to one another?

____

____

____

____

4. What would you estimate the angle between two adjacent faces to be?

______________°

5. In **A-1–4** you discovered the major features by which a mineralogist recognizes galena. How would you describe galena?

____

____

____

____

Step B Before you do this experiment, you must learn the laboratory technique of using a blowpipe.

6. Light the Bunsen burner and cut off its air supply. This produces a yellow flame. Adjust the gas flow so the flame is not more than 2 inches high.

7. Put the mouthpiece of the blowpipe to your lips. Blow through the instrument, directing the tip to the palm of your hand. Do you feel the air jet? If not, the tip is plugged. If this has happened, ask your teacher to clear the tip for you.

8. When you know that the blowpipe is clear, put the tip in the top part of the Bunsen flame and blow gently. Experiment until you learn how to direct the flame as you want. Experiment to find out how to produce a blue flame and a yellow flame in the form of little jets that you can direct. When you are satisfied that you know how to use the blowpipe, go on to Step C.

Step C Galena is a mineral composed of lead and sulfur. You can extract the lead from it by smelting the mineral with carbon. The first step in this process oxidizes, or combines, the sulfur and the lead with oxygen from the air. This is done by heating the mineral in air. The sulfur produces a gas, sulfur dioxide, that escapes. The lead produces lead oxide, a yellowish powder that remains. In the second step the lead oxide reacts with charcoal, which is actually carbon. This step also requires heat. The carbon combines with the oxygen in the lead oxide to produce oxides of carbon and the metal lead. The entire process can be done continuously on a charcoal block.

9. With the tip of a penknife or a pencil, grind a little pit in the charcoal block near one end. Make the hole about 1/4 inch in diameter and 1/8 inch deep.

10. Place a small piece of galena in the pit you have made in the charcoal block. Grasp the block with one hand, at the end farthest from the pit. Hold the block almost horizontally. With the blowpipe, direct the tip of a blue flame against the piece of galena. Keep the flame there for several minutes. What happens?

11. Continue to flame the galena with the tip of the flame from the blowpipe until the substance in the pit is a glowing little ball of molten material. This little ball is called a bead. Change the flame jet to yellow for a few seconds. Stop blowing and let the block and its contents cool. What is the appearance of the bead?

12. Carefully roll the bead out of the pit and onto a piece of paper. Don't lose it! Ask your teacher to cut the bead for you. Examine the cut surface. What color is it?

Step D The product of your investigation may simply be melted galena. See whether you have changed a physical property. Take your product to the anvil and gently tap it with a hammer. Then, take a small piece of galena and place it on the anvil. Tap it with a hammer.

13. What happens?

14. What is one difference between galena and the substance you produced from it?

15. What, probably, is the substance you produced?

NAME ________________________ SECTION ________ DATE ________

INVESTIGATION 5-1

Characteristics of Common Rocks

Aim: To become familiar with the characteristics of some common types of rocks

MATERIALS

Box of rock samples
Hand lens
Dilute hydrochloric acid

Step A The first step in any attempt to classify objects is to sort the collection into two or three major categories. This applies to all kinds of classifying.

1. What are the features by which sedimentary rocks may be distinguished from crystalline rocks?

2. Which of these features may be used to recognize a fragment of a sedimentary rock?

Step B Using the features you noted in **A-2**, separate the specimens of sedimentary rocks in your collection from the others. Set the others aside for study in Step C. Examine your specimens of sedimentary rock.

3. Other than color, what is the most obvious feature that varies from sample to sample?

4. Arrange your collection in a sequence based upon the feature noted in **B-4**.

5. Recognition of the cementing substance in a sedimentary rock requires careful chemical analysis. One of the common cementing agents reacts visibly with dilute hydrochloric acid, producing bubbles of carbon dioxide. What is the name of that cementing agent?

6. Test each of your specimens with 1 drop of dilute hydrochloric acid. Set aside those that produce the reaction noted in **B-6**.

7. With the aid of Appendix II in your textbook, determine the name that best applies to each of your samples of sedimentary rock.

Step C Some kinds of crystalline rock are easily recognized, while others are not. Geologists themselves have different opinions about some specimens. The fact that a specimen is igneous or metamorphic is sometimes almost impossible to decide, especially if the sample is only a fragment.

8. What feature will you use to select the crystalline rock fragments that you think are igneous rock?

9. What features will you use to identify the specimens of metamorphic rock?

____

____

____

____

____

10. Sort your collection of crystalline rock samples into three groups: those you are sure are igneous, those you are sure are metamorphic, and those of which you are uncertain.

11. Study the rock samples that you feel certain are igneous and compare them with the information in Appendix II of your textbook. Decide what you are going to call each sample.

12. Repeat **C-12** with the samples you are sure are metamorphic rocks.

13. Using the knowledge you have gained through the studies you made for **C-12** and **C-13** and the samples you have named, decide upon your "best guess" for the rock names of the samples that puzzled you.

Step D For each sample that was given to you, write a statement patterned after this one: "I believe sample X is a sandstone because it appears to be composed of cemented sand grains and the cement does not react with dilute hydrochloric acid."

I believe sample ________ is a ________________ because

____

____

I believe sample ________ is a ________________ because

____

____

I believe sample ________ is a ________________ because

____

I believe sample ______ is a ____________ because

I believe sample ______ is a ____________ because

I believe sample ______ is a ____________ because

I believe sample ______ is a ____________ because

I believe sample ______ is a ____________ because

I believe sample ______ is a ____________ because

I believe sample ______ is a ____________ because

NAME ____________________ SECTION __________ DATE __________

Effect of Carbon Dioxide and Water on Shell Material

Aim: To explore the effects of carbon dioxide and water on shell material

MATERIALS
Powdered shell material
Test tubes (4)
Soda straws
Bunsen burner
Water

Step A Put a tiny pinch of powdered shell in each of 2 test tubes. Add water to fill each test tube half full. Set one of these test tubes aside. By means of a soda straw, blow into the water in the other test tube. Be sure that the lower end of the straw is not more than ½ inch from the bottom of the test tube. Blow gently enough to prevent the water from splashing out of the test tube. Blow for 5 or 6 minutes.

1. How much of the powdered shell disappeared into solution in the test tube into which you blew? Check the correct answer.

( ) None ( ) Some ( ) All

2. How much of the powdered shell disappeared into solution in the test tube that you set aside?

( ) None ( ) Some ( ) All

Step B Let the test tubes stand until the powdered shell has settled to the bottom. Very carefully pour off half the water from each into clean, dry test tubes. Heat these test tubes over the Bunsen burner.

3. What happened to the water from the test tube into which you blew?

____

____

____

____

4. What happened to the water from the test tube into which you did not blow?

5. Explain what you think happened in this experiment.

NAME________________________________ SECTION________ DATE____________

INVESTIGATION 6-1

Effect of Particle Shape on Settling Rate

Aim: To discover whether the shape of a particle affects the rate at which it settles in water

MATERIALS

- Glass cylinder
- Water
- Modeling clay
- Stopwatch

Step A Roll the modeling clay into a cylinder that is 5 inches long and has a uniform diameter. Cut the clay cylinder into 10 equal pieces. Roll each piece into a ball.

1. Fill the glass cylinder with water to about 1½ inches from the top. Measure from the outside the depth of the water. What is the depth?

______________cm

Step B Hold a ball of modeling clay so that it just touches the water. When the timer is ready, let go of the ball. Note on the stopwatch how long it takes the ball to reach the bottom of the water. Record the results of 10 trials, one with each ball, in the following table.

2.

Trial 1	______________sec	Trial 6	______________sec
Trial 2	______________sec	Trial 7	______________sec
Trial 3	______________sec	Trial 8	______________sec
Trial 4	______________sec	Trial 9	______________sec
Trial 5	______________sec	Trial 10	______________sec

Sum ______________sec

Average ______________sec

3. How would you describe the path of a ball as it falls through water?

____

____

____

Step C Recover the 10 modeling-clay balls and flatten each one into a disk about the size of a nickel. Repeat Step B and record the results.

4.

Trial 1 ____________sec

Trial 2 ____________sec

Trial 3 ____________sec

Trial 4 ____________sec

Trial 5 ____________sec

Trial 6 ____________sec

Trial 7 ____________sec

Trial 8 ____________sec

Trial 9 ____________sec

Trial 10 ____________sec

Sum ____________sec

Average ____________sec

5. How would you describe the path of a flat disk as it falls through the water?

____

____

____

Step D Study the results of the experiments performed in Steps B and C.

6. In which experiment did the objects fall more rapidly?

Step ____________

7. In which experiment was there greater variation in the amount of time it took the individual objects to fall through the column of water?

Step ______________

8. Does the shape of an object affect the time it takes to settle in water?

____

9. Why do you think the shape of an object affects its settling time in water?

____

____

____

____

____

____

Step E Combine two of your clay pieces into one and roll it into a ball. Do this with all your material, making 5 balls. This will produce balls that have about twice the mass of those you used in Step B. Repeat Step B with these objects.

10.

Trial 1 ______________sec

Trial 2 ______________sec

Trial 3 ______________sec

Trial 4 ______________sec

Trial 5 ______________sec

Sum ______________sec

Average ______________sec

11. Compare the result of Step E with that of Step B. What was the average time in Step B?

______________sec

What was the average time in Step E?

_______________sec

12. In which step did the balls settle more rapidly?

____

13. Did the density of the objects you used change from Step B to Step E? Why?

____

____

14. Did the shape of the masses differ materially between Step B and Step E? Why?

____

____

15. What did change between the two experiments?

____

____

16. Make a general statement summarizing your results of the entire series of experiments.

____

____

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____

____

NAME________________________ SECTION________ DATE____________

INVESTIGATION 6-2

Constructing a Geologic Column

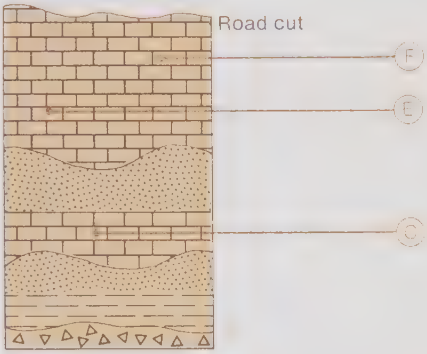


Figure 1

Aim: To construct a geologic column

When a geologist constructs a geologic column for a region such as a county or a state, he combines data from many areas into one column. Each of the short local columns is called a section. Pages 67–69 in your textbook describe how a column is made from sections. Use them as a guide while you work on this investigation.

Look at Figures 1–4. They are diagrams of sections from 4 sites that are within a mile of one another. Each section shows the sequence of rocks it contains. The rock symbols used are those that are generally accepted by geologists. The interpretation of the symbols is shown in Figure 5. Sometimes two different symbols seem to overlap. This means that the rock is an intermediate of the two types. Thus, the symbol for limestone overlapped by the symbol for sandstone indicates "sandy limestone." Fossils were found in each of the columns. Their presence is indicated by letters, with A as the oldest and F the youngest (see Figure 6).

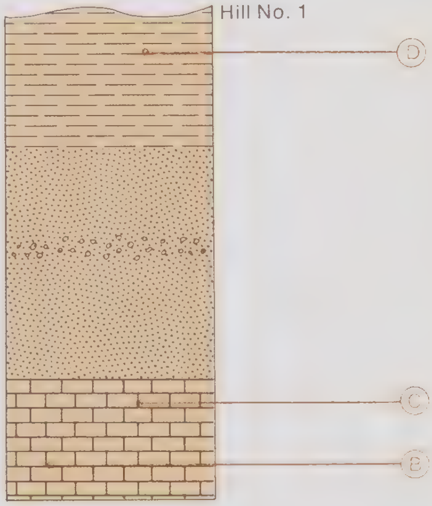


Figure 2

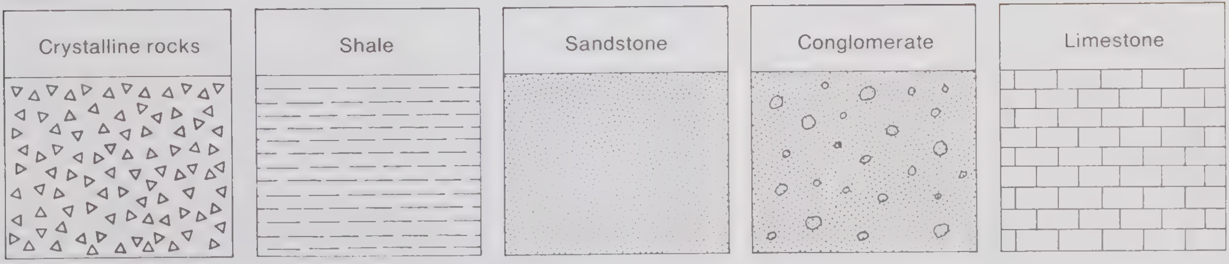
Step A Carefully study each section. By comparing the fossils and their position in the sections, decide which section represents the lowest part of the geologic column that you are constructing.

1. Which section contains the oldest rocks and fossils? ____________

2. Which section contains the youngest rocks and fossils? ____________

3. Which section contains both the oldest and the second youngest rocks in the column? ____________

Figure 5



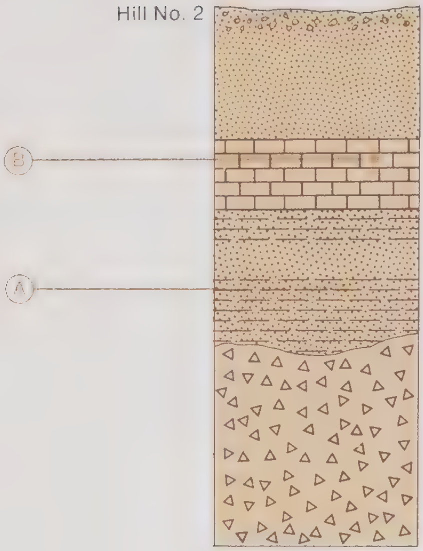


Figure 3

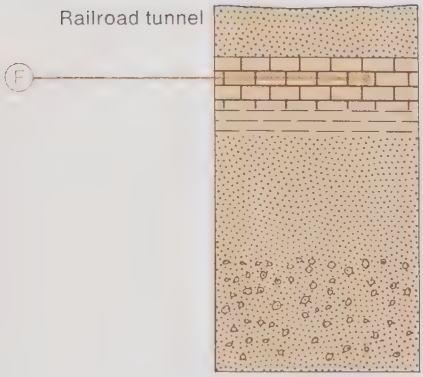


Figure 4

4. Which section connects the section showing the oldest rocks with that showing the youngest rocks?

____

Step B Now you are ready to build the geologic column. Transfer the information from the oldest section to the bottom of the area labeled "Geologic Column" at the right edge of Figure 7. Label each stratum in the column with the name of the type of rock represented. You need not fill the whole area with the symbol for the rock. Add to your column the additional information from the section you noted in your answer to **A-4**.

5. Why do you plot the additional material from this particular section next?

____

____

____

____

____

____

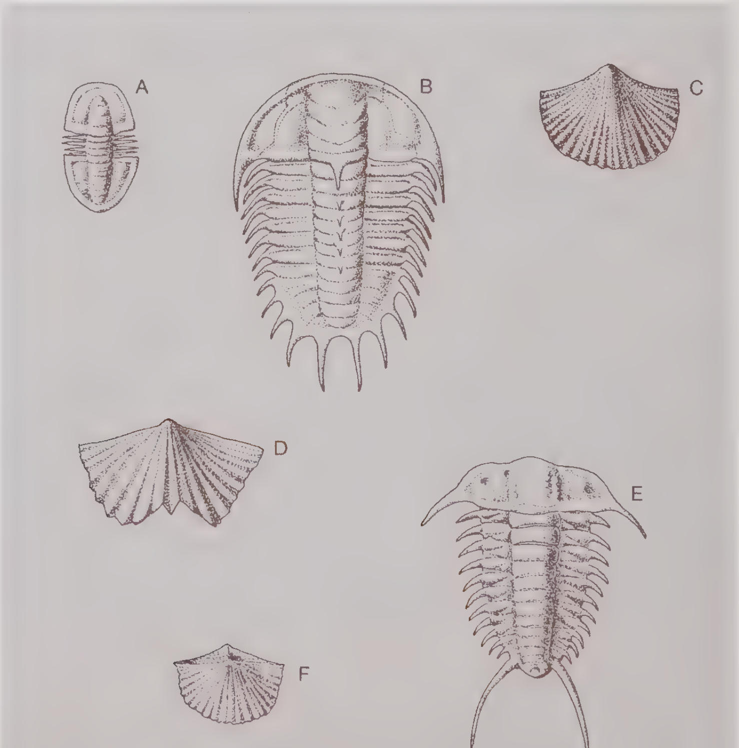


Figure 6

Step C Complete your geologic column. To the left of it, you will find four very slender columns. Blacken the part of the slender column labeled 1 to indicate the distance Section 1 represents of your complete "Geologic Column." The rocks and fossils in Section 1 will give you a clue. Do this for all four sections.

6. Why have you blackened two unconnected parts in slender column 1?

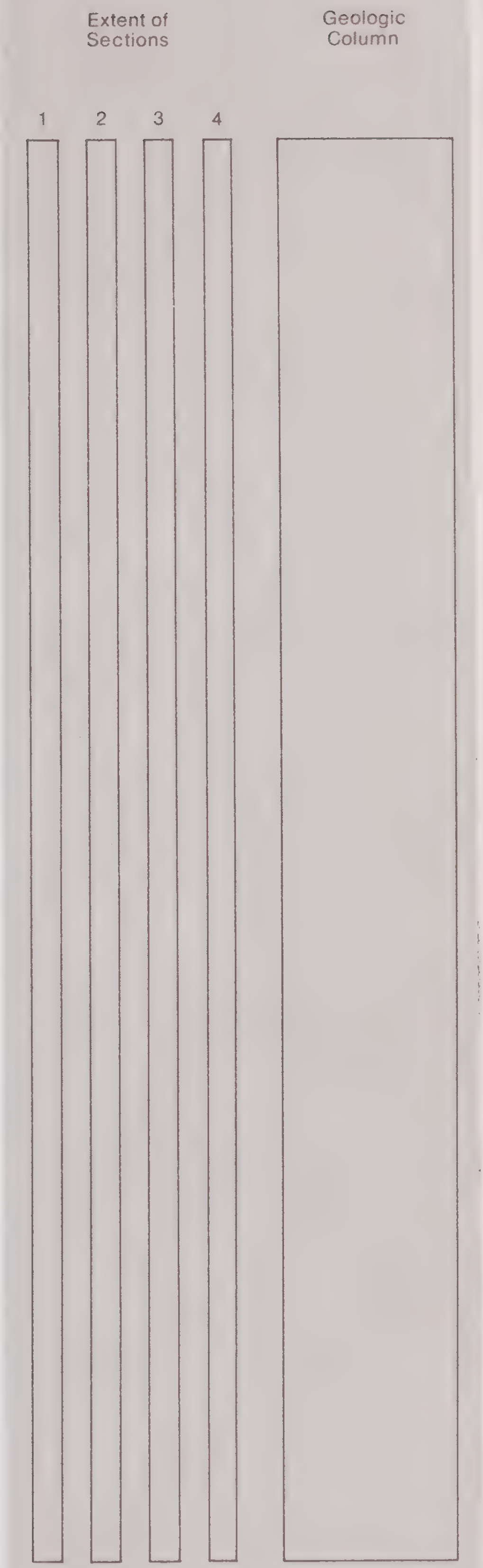


Figure 7

NAME ______ SECTION ______ DATE ______

INVESTIGATION 8-1

The Meaning of the Term Half-life

Aim: To examine the meaning of *half-life*

MATERIALS

Identical objects; use marbles, ball bearings, matchsticks, or seeds (256)
Box to hold these objects

Step A It is often difficult to understand the meaning of the term *half-life* as it applies to radioactive elements. In this investigation you will demonstrate what this term means. It will take several days to complete the investigation. The box represents a crystal that contains radioactive atoms, all of the same kind. The 256 identical objects represent these atoms. We will assign a half-life of one day to this particular kind of radioactive atom. Each day, half of the atoms in the crystal will decay. Each day, remove from the box half of the objects that are there. Those that remain represent the undecayed atoms.

1. How many atoms will decay during the first day?

______

Step B On the morning of the second day, remove the proper number of decayed atoms, which you indicated in **A-1**. Each morning, remove the proper number of decayed atoms and record the appropriate data in Table I.

TABLE I

Day of experiment	Number of radioactive atoms at beginning of this day	Number of atoms that decayed during this day
1st day		
2nd day		
3rd day		
4th day		
5th day		

6th day		
7th day		
8th day		
9th day		
10th day		

Step C The problem that faces us is this: What happens when only 1 radioactive atom is left?

2. What is the definition of the term *half-life*? (If you don't remember, see page 101 in your textbook.)

3. When the number of atoms is reduced to 1, there is only a 50-50 chance that the one atom will decay in the next half-life. We will let the flip of a coin decide whether the atom decayed. We will say that if the coin lands heads up, the atom did not decay, and if it lands tails up, the atom did decay. Beginning the morning after the day when only 1 radioactive atom is left, determine by flipping a coin whether the atom decayed. Each morning, make the decision according to the flip of a coin and enter the results in Table I.

Step D One way to discover how many radioactive atoms will remain after a certain period of time has elapsed is to make a table like Table I, which you derived experimentally. However, it would be useful to have a quicker way to find this information. Let us examine the data in Table I. How could you arrive at the number of radioactive atoms left at the beginning of the fourth day by direct calculation? You know that each day the number was reduced by one half. We can indicate this mathematically as $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$, because four decay periods had passed. Another way to write it is in power; thus, $\frac{1^4}{2^4}$ also represents four decay periods. 1^4 is 1 and 2^4 is 16; therefore, 1/16 of the original atoms should be present after 4 half-life periods.

4. Is the number of radioactive atoms you entered for the beginning of the fourth day 1/16 of the number you started with? Prove it.

NAME ______________________ SECTION ______ DATE ______

INVESTIGATION 9-1

Force Needed to Overcome Friction

Aim: To discover the force needed to overcome friction

MATERIALS

- Board, 6″ x 1″ x 30″
- Block of wood, 2″ x 4″ x 6″, with a screw eye in one end
- Spring scale
- Piece of coarse sandpaper, 6″ x 8″
- Meterstick
- Piece of string, 10″ long

Step A Place the board flat on your desk, with the smooth side up. Place the block of wood on one end of the board so that the screw eye points toward the other end of the board. Tie one end of the string to the screw eye and make a loop in the other end. Hook the spring scale into the loop. Check Figure 1 to be sure you have assembled the apparatus correctly.

1. Slowly pull at the block with the spring scale. Observe the stress, which is the number of grams of pull that is needed to start the block sliding. Your action overcame static friction. What amount of force, in grams, is needed to overcome static friction?

______ g

2. Again pull the block along the board. This time, note the least amount of pull necessary to keep the block moving after you have overcome static friction. What amount of force, in grams, is needed to overcome kinetic friction?

______ g

Step B Repeat Step A, with this change: Place two or three textbooks under one end of the board to produce a slope.

3. What amount of force is necessary to overcome static friction now?

______ g

4. What amount of force is necessary to overcome kinetic friction now?

______ g

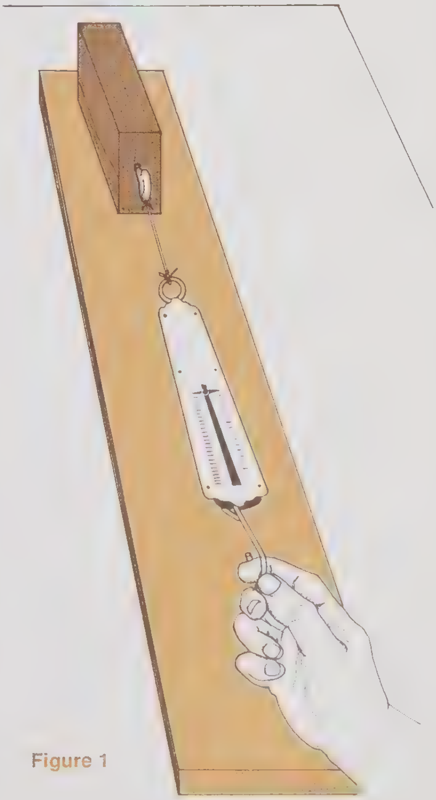


Figure 1

5. Were the forces applied in **B-3** and **B-4** greater, or less, than those applied in **A-1** and **A-2**?

____

6. What caused this change in the amounts of force?

____

Step C Repeat Step A. This time, use the other side of the board, and place the block of wood on the end with the sandpaper.

7. What amount of force is necessary to overcome static friction?

________________g

8. What amount of force is necessary to overcome kinetic friction?

________________g

9. Were the forces applied in **C-7** and **C-8** greater, or less, than those applied in **A-1** and **A-2**?

____

10. Explain the cause for your answer in **C-9**.

____

____

____

____

NAME________________________ SECTION__________ DATE__________

INVESTIGATION 9-2

Rate of Heat Transmission in Rock and in Water

Aim: To determine and compare the rate of heat transmission in rock and in water

MATERIALS

- Special "rock" sample
- Thermometers (3)
- 1-liter beaker
- Asbestos-gauze mat
- Pipestem triangle
- Tripod or ring stand with large ring
- Watch with second hand
- Bunsen burner
- Water

Step A Set up the apparatus as shown in Figure 1. Lower the "rock" into the beaker so that it rests firmly on the pipestem triangle. Put enough water into the beaker to bring the level to approximately ½ inch from the top of the rock sample. *Carefully* lower a thermometer to the bottom of each hole in the rock sample. Lower a third thermometer into the water.

1. Read and record below the temperatures of the water and the rock. Read these to the nearest ½°C.

Temperature of rock, near margin ______________°C

Temperature of rock, near center ______________°C

Temperature of water ______________°C

Step B In this investigation you will be required to note and record the temperatures of the water and the interior of the rock sample at two places over a period of time while they are being heated. Two of you will read the temperatures of the interior of the rock. Another will carefully stir the water with a thermometer and read its temperature. The fourth will be the timer-recorder. You will read the temperatures every 30 seconds.

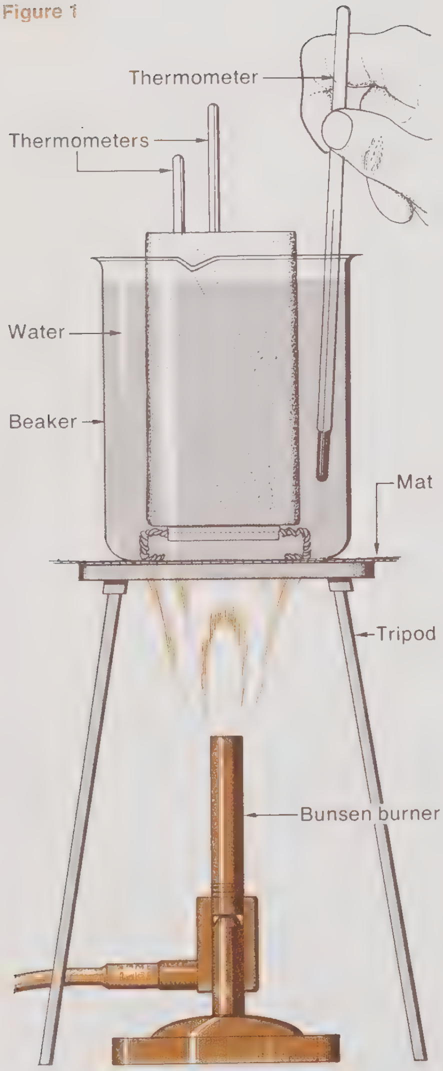
Light the Bunsen burner and place it under the beaker containing the water and the rock sample. Start timing when the Bunsen burner is placed under the beaker. Start stirring the water *GENTLY* at the same time.

2. At the end of each 30 seconds, the timer will call "Mark!" The thermometer readers will make note of the temperatures at that time and report them to the timer-recorder, who should write them in the appropriate place in Table I.

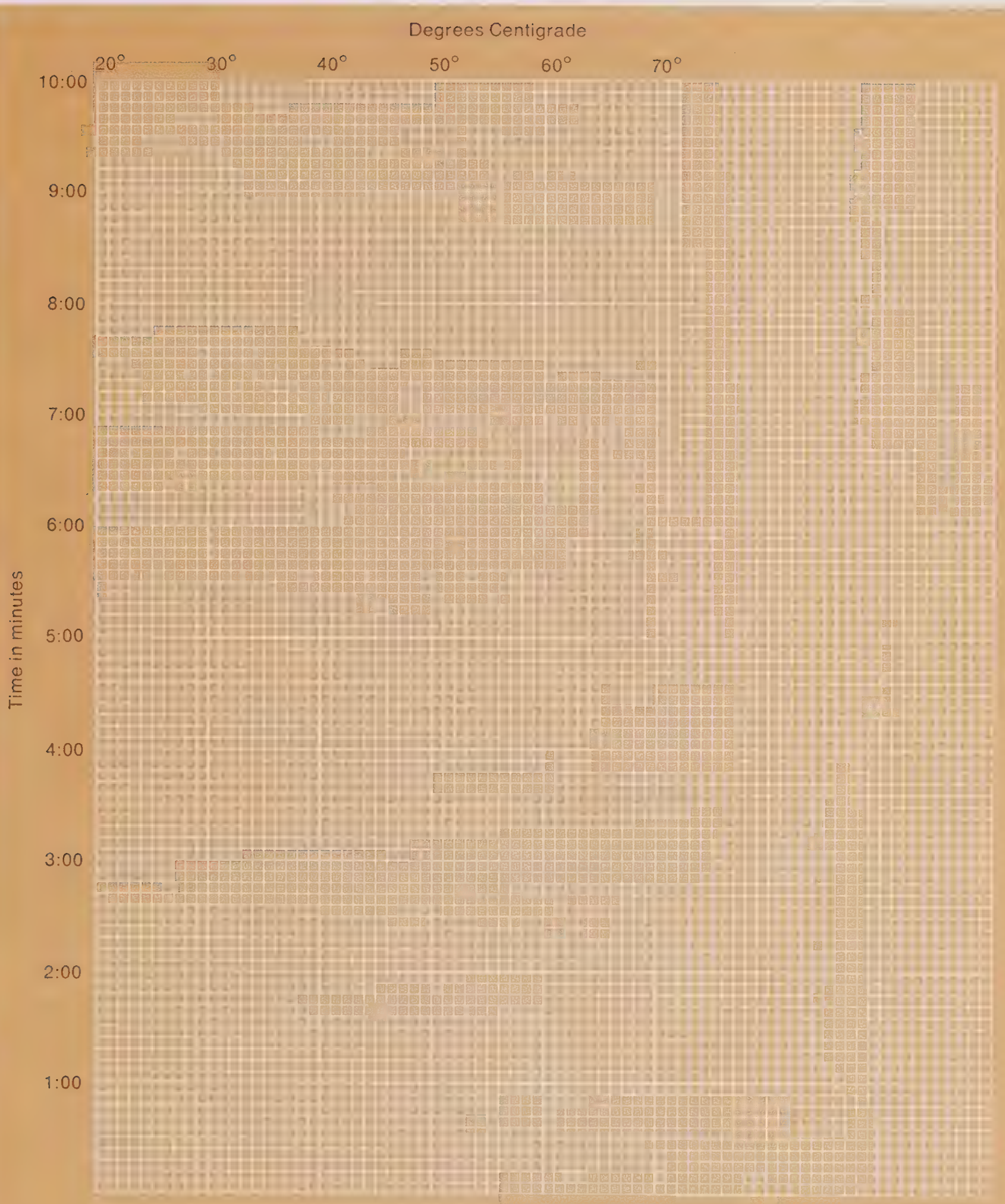
TABLE I

	Temperature				Temperature		
Time	Water	Rock Margin	Rock Center	Time	Water	Rock Margin	Rock Center
0:00				7:30			
0:30				8:00			
1:00				8:30			
1:30				9:00			
2:00				9:30			
2:30				10:00			
3:00				10:30			
3:30				11:00			
4:00				11:30			
4:30				12:00			
5:00				12:30			
5:30				13:00			
6:00				13:30			
6:30				14:00			
7:00				14:30			
				15:00			

Figure 1



Step C The other team members should transfer the data to their laboratory books. Plot the data on the graph paper included in this investigation.


Degrees Centigrade
20°
30°
40°
50°
60°
70°
10:00
9:00
8:00
7:00
6:00
5:00
4:00
3:00
2:00
1:00
Time in minutes

3. What was the highest temperature recorded for the water?

______________°C

4. How long did it take the water to reach that temperature?

______________min ______________sec

5. What was the highest temperature recorded by the thermometer near the margin of the rock?

______________°C

6. How long did it take the margin of the rock to reach the temperature noted in **C-5**?

______________min ______________sec

7. What was the highest temperature recorded by the thermometer at the center of the rock?

______________°C

8. How long did it take the center of the rock to reach the temperature noted in **C-7**?

______________min ______________sec

9. Did the center of the rock reach the same maximum temperature that the water reached?

____

10. What may be an explanation for your answer to **C-9**?

____

____

____

____

____

____

____

Step D In this step you will examine the data you have accumulated in order to discover the rates of temperature change in the rock and in the water.

11. From the data taken near the end of the investigation, select a temperature recorded for the center of the rock. What temperature did you select?

__________°C

12. At what time was the observation in **D-11** made?

__________min __________sec

13. At what time, from your data or graph, was the margin of the rock at the temperature noted in **D-11**?

__________min __________sec

14. What temperature was the center of the rock at the time noted in **D-13**?

__________°C

15. What was the difference in the temperatures of the margin and center of the rock at the time noted in **D-13**?

__________°C

16. How long did it take for the temperature in the center of the rock to make the change noted in **D-15**? (See **D-12** and **D-13**.)

__________min __________sec

17. What was the change in temperature per minute? (See **D-15** and **D-16**.)

__________°C/min

18. Consult your data and graph. At what time was the water at the temperature noted in **D-11**?

__________min __________sec

19. At what time was the water at the temperature noted in **D-14**?

__________min __________sec

20. How long did it take the water to make this change in temperature? (See **D-18** and **D-19**.)

__________min __________sec

21. In degrees per minute, what was the rate of change in the temperature of the water?

__________°C/min

22. In which substance did the temperature change more rapidly, the water or the rock?

____

Step E You know that temperature and heat are not the same. You measured the rate of temperature change in your rock and in water under the conditions of your investigation. Now you will study the rates at which heat flows through water and through your rock.

23. In **D-21** you calculated the rate of temperature change in the water. How many calories were supplied per minute to 1 gram of water to produce this change?

__________cal/min

24. The specific heat of the rock that you used can be taken as 0.19 cal/g/°C. How many calories are needed to raise the temperature of 1 gram of your rock to 1°C?

_____________cal

25. In **D-17** you estimated the rate at which the temperature of your rock changed. How many calories per minute were needed to make that change for 1 gram of the rock?

_____________cal/min

26. Through which substance, water or rock, did heat flow more rapidly? (See **E-23** and **E-25**.)

____

NAME ____________________ SECTION __________ DATE __________

INVESTIGATION 9-3

Specific Heat of Sand

Aim: To measure the specific heat of sand

MATERIALS
Sand Small empty can Thermometer, Celsius scale Balance and weights, metric scale 600-ml beakers (2) Water Heat source

Step A Before you do this investigation you will need to review the meanings of certain words. If you do not know the terms below, look them up in your textbook.

1. How do you define a calorie?

____

____

____

2. How do you define specific heat?

____

____

____

Step B In this investigation you will add a known weight of sand at a known temperature to a known weight of water at a known temperature.

3. What is the weight of the can to the nearest 0.1 g?

__________ g

4. Fill the can with sand to a depth of 1″. What is the weight of the combination to the nearest 0.1 g?

__________ g

5. What is the weight of the sand? (**B-4** minus **B-3**)

________________g

6. What is the weight of one of the beakers to the nearest 0.1 g?

________________g

7. Fill that beaker with water about 2 inches deep. What is the weight of the combination to the nearest 0.1 g?

________________g

8. What is the weight of the water in the beaker? (**B-7** minus **B-6**)

________________g

Step C Heat the sand in its container by putting it into the *second* beaker with enough water to come halfway up the side of the sand container. Be very careful that no water gets into the sand. Place the setup over a heat source and bring the water to a boil. Stir the sand with the thermometer. Do this carefully so that you do not break the thermometer; it is fragile! When the sand has reached 91°C, remove the thermometer.

Step D Place the thermometer in the water that you weighed.

9. Stir gently, and read and record the temperature.

________________°C

10. Pour the hot sand into the beaker of weighed water and stir the sand in the water with the thermometer. What is its temperature?

________________°C

11. Stir again. What is the temperature now?

________________°C

12. Record here the higher of the two temperatures recorded in **D-10** and **D-11**.

________________°C

Step E You now have all the information you need to calculate the specific heat of the sand.

13. What was the increase in the water temperature? (**D-12** minus **D-9**)

________________°C

14. What weight of water was heated? (See **B-8**.)

________________g

15. How many calories were transferred from the sand to the water? (**D-13** times **E-14**)

________________cal

16. Where did this heat come from?

____

17. What weight of sand was used? (See **B-5**.)

________________g

18. How much heat was transferred from each gram of sand?

________________cal/g

19. What was the temperature change in the sand? (Step C minus **D-12**)

________________°C

20. How much heat was lost by each gram of sand for each degree Celsius? (**E-18** divided by **E-19**)

________________cal/g/°C

21. What is the specific heat of the sand? (See **A-2**.)

________________cal/g/°C

NAME________________________ SECTION________ DATE__________

INVESTIGATION 10-1

Does Air Contain Water?

Aim: To discover whether air contains water

MATERIALS

- Powdered copper sulfate crystals
- Test tubes (1 or 2)
- Bunsen burner
- Watch glass
- Piece of white paper, or 3″ x 5″ card
- Test-tube holder

Step A Place into a test tube about as much powdered copper sulfate as you can pile on a penny. Hold the test tube almost horizontal and gently shake it so that the copper sulfate spreads out evenly along the side of the test tube.

1. What is the color of copper sulfate?

____

Step B Using a test-tube clamp, hold the test tube nearly horizontal over the Bunsen burner. Gently shake the tube from side to side so that all the material is well heated.

2. As heating progresses, what happens to the color of the copper sulfate?

____

____

3. What forms on the inner wall of the test tube near the cool open end?

____

____

4. What is the probable source of what you observed in **B-3**?

____

____

____

5. Continue heating until the test tube is free of everything except the copper sulfate. This is called anhydrous copper sulfate.

Step C Transfer a little of your anhydrous copper sulfate to a second test tube or a watch glass. Add one drop of water to the material.

6. What happens?

7. What does this change indicate?

8. How can you test for the presence of water in air?

Step D To test your hypothesis stated in **C-8**, place a small amount of anhydrous copper sulfate on a piece of white paper or on a watch glass.

9. Breathe across the anhydrous copper sulfate. What happens?

10. What does this result suggest?

11. In what state is the water?

12. Where did it come from?

Step E Place the rest of your anhydrous copper sulfate on a watch glass or on a piece of white paper. Leave it there until the next class.

13. What happened to the color of the anhydrous copper sulfate?

14. How do you explain this?

NAME____________________ SECTION__________ DATE__________

INVESTIGATION 10-2

Does Dry Rock Contain Water?

Aim: To determine whether a dry rock contains water

MATERIALS

- Piece of gypsum
- Mortar and pestle
- Bunsen burner
- Hard-glass test tube
- Test-tube holder

Step A Examine the piece of gypsum. Feel it and squeeze it. The chemical formula for gypsum is $CaSO_4 \cdot 2H_2O$.

1. Does the gypsum feel wet? ____________

2. Can you squeeze any water from the gypsum?

____

Step B Put the gypsum in the mortar and use the pestle to grind it to a powder. Pour enough powdered gypsum into a hard-glass test tube to fill it to a depth of about ½ inch. Hold the test tube in an almost horizontal position; tap gently to distribute the powdered gypsum in the lower quarter of the test tube. Holding the test tube with a test-tube holder, heat the lower quarter of the tube. Observe what happens throughout the entire test tube.

3. What were your observations?

____

____

____

____

____

____

____

4. Examine the formula for gypsum given in Step A. How would you explain your observation in **B-3**?

5. Does this prove that the liquid droplets are water? Why?

6. Refer to Investigation 10-1 and use it as a reference to outline a way to test the liquid to determine whether or not it is water. How would you test the liquid?

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INVESTIGATION 10-3

Estimating the Heat of Condensation

Aim: To estimate the heat of condensation

MATERIALS

Steam generator (boiler): 600-ml Erlenmeyer flask and 2-hole stopper to fit
Glass and rubber tubing
Water trap: 125-ml Erlenmeyer flask and 2-hole stopper to fit
Bunsen burner
250-ml beaker
Water
Thermometers (2)
Balance and weights

Step A Assemble the apparatus as shown in Figure 1. Fill the boiler half full of water. Place it over the Bunsen burner and light the flame. Proceed to Step B while you are heating the water in the boiler to produce steam.

Step B

1. What is the weight of the empty, dry beaker to the nearest 0.1 g?

________________g

2. Fill the beaker two-thirds full of water and then weigh the beaker and water. What is its weight to the nearest 0.1 g?

________________g

3. Place a thermometer in the beaker of water and weigh the combination. What is the weight of the combination to the nearest 0.1 g?

________________g

4. What is the temperature of the water? *Be sure to leave the thermometer in the beaker of water.*

________________°C

5. What is the weight of the water in the beaker? (**B-2** minus **B-1**)

________________g

Step C When steam is flowing freely from the tube attached to the water trap, put the mouth of the tube into the beaker of water. Be sure the mouth of the tube is near the bottom of the beaker. Allow steam to flow into the beaker of water for 5 or 10 minutes.

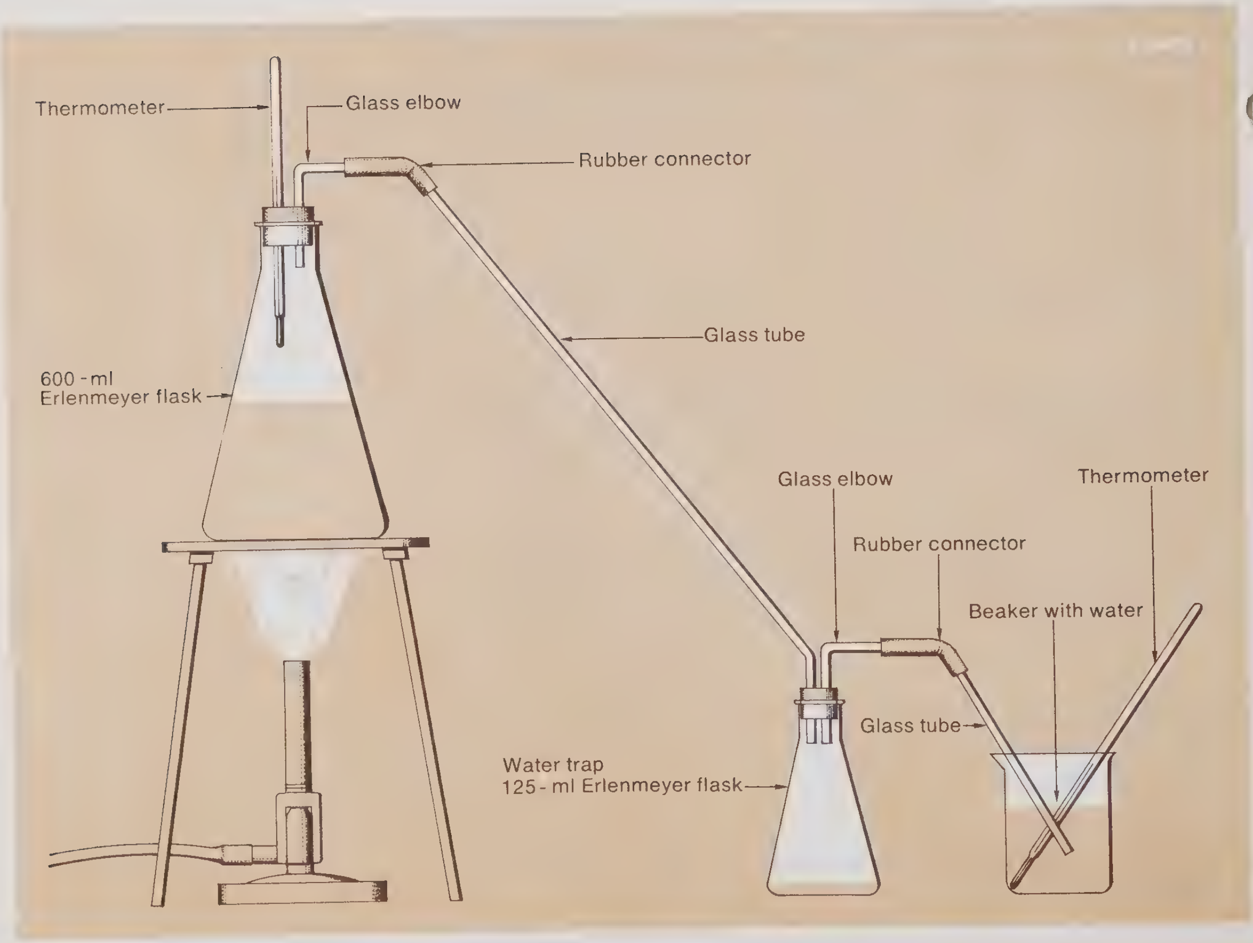
6. Read the temperature of the steam by means of the thermometer in the stopper of the boiler. What is its temperature?

_______________°C

7. What is the temperature of the water in the beaker? (Stir the water gently to be sure it is well mixed.)

_______________°C

8. Turn off the Bunsen burner. Disconnect the glass tube that discharged steam into the beaker of water. *Leave the tube in the beaker. Do not lose any water.*



9. Weigh the beaker, water, tube, and thermometer to the nearest 0.1 g. What is the total weight?

______________g

10. Remove the glass tube from the beaker of water. Dry the tube inside and out. What is its weight to the nearest 0.1 g?

______________g

11. Subtract the weight of the tube from the result you got in **C-9**. What is the weight of beaker, water, and thermometer?

______________g

12. What is the weight of the water that condensed from steam? (**C-11** minus **B-3**)

______________g

13. What was the weight of the water in the beaker at the beginning of the investigation? (**B-2** minus **B-1**)

______________g

14. What was the weight of the water in the beaker at the end of the investigation? (**C-12** plus **C-13**)

______________g

You now have all the data needed for further calculations.

Step D From the data you have accumulated, it is possible to trace the heat that warmed the water in the beaker.

15. What was the change in temperature of the water in the beaker? (**C-7** minus **B-4**)

______________°C

16. How many calories were added to the water with which you started the investigation? (**D-15** times **C-13**)

____________________cal

17. Look at **C-6** and **C-7**. What was the change intemperature that occurred for the water that condensed from the steam?

______________°C

18. Look at **C-12** and **D-17**. How many calories were lost by the water that was produced from steam?

________________________cal

19. The heat noted in **D-18** was added to the water with which you started the investigation. What else added heat to that water?

____

20. How many calories were released by condensation of the steam? (**D-16** plus **D-18**)

_______________cal

21. How many calories were added to the water by one gram of condensing steam? (**D-20** divided by **C-12**)

________________________cal

NAME____________________________ SECTION________ DATE__________

INVESTIGATION 11-1

The Latitude from the North Star

Aim: To determine the latitude from the North Star

MATERIALS

Cardboard
Thread
Weight (about 20 g)
Paper clip
Protractor

Step A Look at Figure 1 to see how to construct your instrument. Put a pinhole in one corner of the cardboard as shown. Poke the end of thread through the hole and tie a small paper clip to the thread. Pull the thread tight, with the paper clip against the cardboard. Tie the small weight to the free end of the thread.

Step B Locate the North Star off the handle of the Little Dipper. Hold the cardboard vertically so that you can sight along the upper straight edge. Be sure that the weight is hanging free and the thread is *just* touching the flat surface of the cardboard. Sight along the straight edge toward the North Star. When the star is just on the edge of the cardboard, carefully hold the thread in place against the cardboard with your thumb and fingers.

1. With a pencil, make a mark on the cardboard near the lower edge where you are holding the thread.

2. With a ruler, draw a line from the mark you made, through the hole through which the thread passes, to the upper straight edge of the cardboard along which you sighted. If you were to extend this zenith line straight up into the sky, it would lead to the zenith point. The zenith angle is the angle formed between the zenith line and the sight line to the North Star.

3. With a protractor, measure the angle between the line you drew and the edge of the cardboard along which you sighted. This is equal to the actual *zenith angle* of the North Star, as shown in Figure 1. What is the zenith angle of the North Star?

________________ °

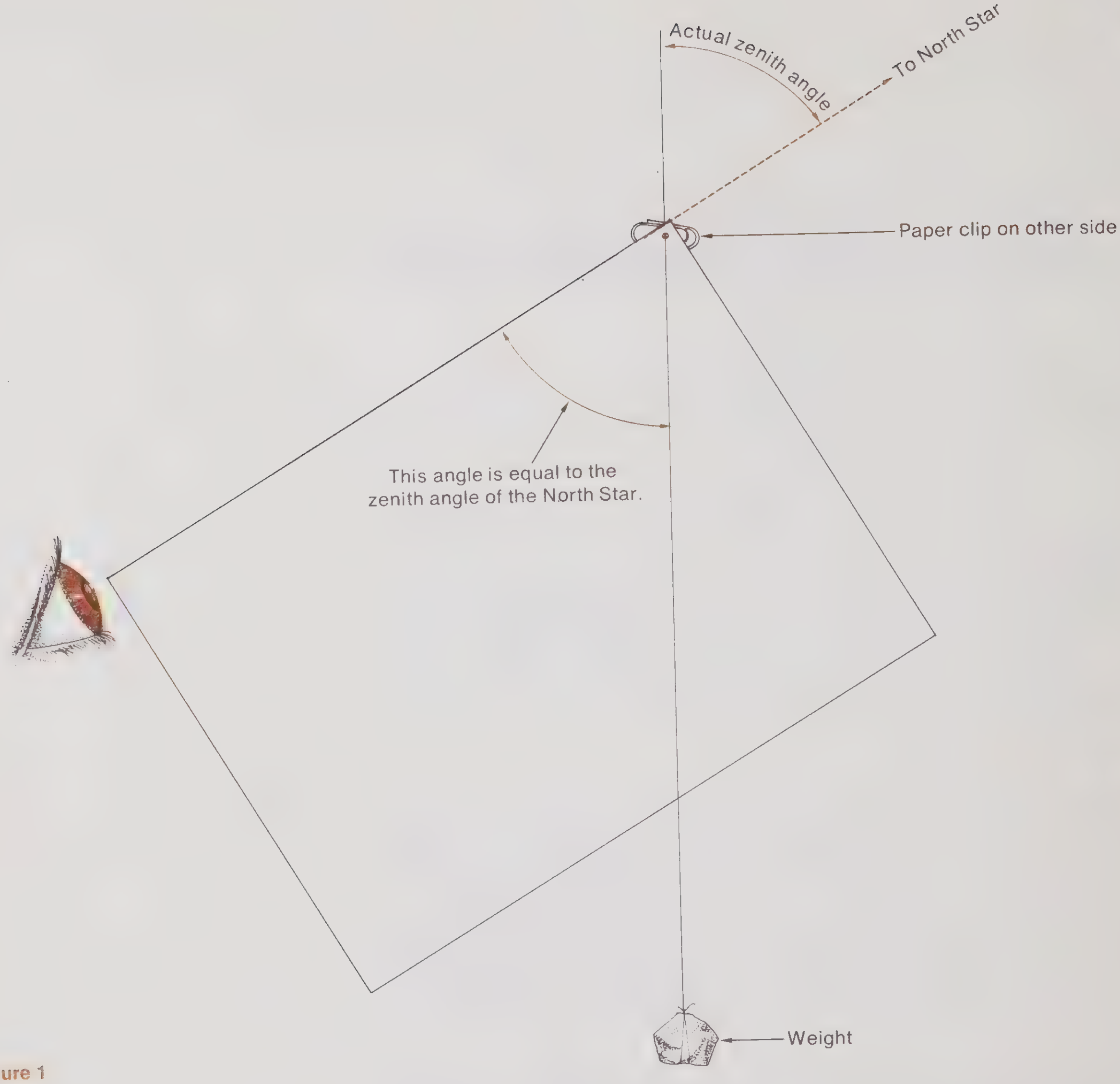


Figure 1

4. Look at Figure 2. Consider the pinhole in Figure 1 as the center of the earth in Figure 2. Consider yourself as the observer standing on the surface of the earth. The distance between you and the center of the earth is negligible, since the North Star is so far away. Therefore, you can assume that the zenith angle starts at the surface of the earth. In other words, you can now say that the zenith angle lies between the zenith line and the line from you to the North Star.

5. Now we want to find the altitude angle. This is the angle formed between the horizon and the line from you to the North Star. You can find the altitude angle once you know that the zenith line and the horizon form a 90° angle. Using this knowledge and the information in **B-3**, what is the altitude angle of the North Star?

______________ °

6. Notice in Figure 2 that the latitude angle plus the zenith angle equal 90°. How many degrees is the latitude angle?

_______________°

7. Which two angles in Figure 2 are equal?

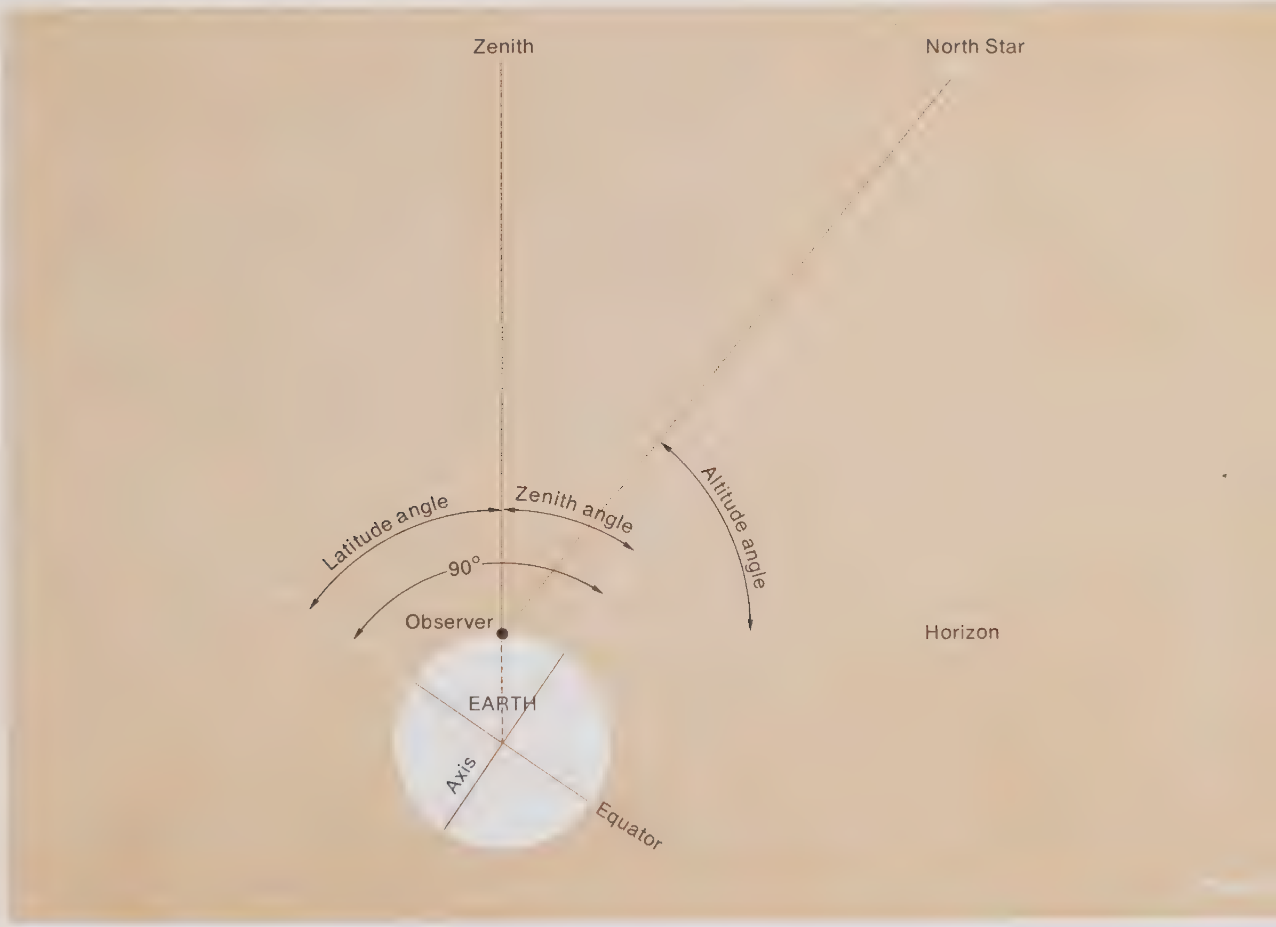
____

8. From a map in an atlas, determine the latitude of the place from which you made your observation.
What is the latitude indicated in the atlas?

_______________°

9. How much error is there between the atlas latitude and your determination of the latitude?

_______________°



10. How do you account for the error?

Step C If you want to determine the zenith angle of the sun, you should not sight directly toward it. The sun is so bright that it can damage your eyes. Instead, do it this way: Push two round-headed pins through the cardboard near the sighting edge, one at one end and the other at the other end. Point the cardboard toward the sun so that the shadows of the two pinheads fall upon each other. Hold the thread in place against the cardboard and draw the line that represents the thread. Measure the angle between that line and a line between the two pinholes made by the round-headed pins. That angle is the sun's zenith angle. From this angle, you can also determine the sun's altitude angle.

NAME ______________________ SECTION______ DATE______

INVESTIGATION 11-2

Effect of Changing the Length of an Hour

Aim: To discover what happens when the length of an hour is changed

Step A Suppose one hour were made up of 30 minutes, each minute the same length of time as the minute we use. We will call these new hours "short hours."

1. How many short hours would there be in a day?

______________sh hr

2. How many short hours would there be between sunrise and sunset on March 21?

______________sh hr

3. Through how many degrees does the sun appear to pass in a conventional hour?

______________°

4. Through how many degrees would the sun pass in a short hour?

______________°

5. Washington uses 75th-meridian time and Denver uses 105th-meridian time. What is the conventional time in Denver when it is noon in Washington?

____

6. What would be the short-hour time in Denver when it is noon in Washington?

____

Step B Suppose we put the day on a decimal system, with 10 hours in the day. We will call these hours "deci-days." We would need no minutes because we then could use decimals of deci-days.

7. How many degrees of sky would the sun pass through in a deci-day?

______________°

8. Look back at **A-5**. What is the angular difference, as measured by the difference in degrees, between the time meridians of Washington and Denver?

______________°

9. What would be the deci-day time difference between noon at Washington and noon at Denver?

____

____

____

____

10. If school started at 8:00 A.M. conventional time, at what time would it start in deci-days? Hint: Convert 8:00 A.M. to a decimal of a day.

____

____

____

____

11. If school closed at 3:00 P.M. conventional time, what time would this be in deci-days? Hint: Change 3:00 P.M. to time on a 24-hour clock instead of a 12-hour clock.

____

____

____

____

12. How many hours and how many deci-days would school be in session?

____

____

13. How many minutes are there in a day?

____________min

14. How many milli-days are there in a day?

____________milli-days

15. How many minutes are there in a milli-day?

____________min

16. How many hours are there in a deci-day?

______________hr

17. If we adopted deci-days instead of hours, would there be any change in the length of a year? Why?

____

____

____

____

18. If we change to deci-days from hours, would there be any change in the length of a day?

____

____

____

____

NAME ____________ SECTION ______ DATE ______

INVESTIGATION 11-3

Effect of the Sun's Angle on Insolation

Aim: To discover the effect of the sun's angle on insolation

MATERIALS

Ruler with a millimeter scale
Protractor

Step A The parallel lines drawn in the margin of this step are exactly 1 cm apart. Let the upper line represent the horizontal ground. With a protractor, erect two parallel lines exactly 1 cm apart at 90° to the horizontal ground line. Extend these lines across both parallel lines. Shade the square that is formed. This represents the area covered by a sunray with a cross section of 1 cm^2 as it strikes the ground at the Tropic of Cancer at noon on June 21.

1. What is the area of horizontal ground struck by the sunray?

____________ cm^2

Step B On December 21 the sun at noon is 47° south of the zenith at the Tropic of Cancer. Using the two parallel lines spaced exactly 1 cm apart, construct the area covered by a sunray whose cross section is 1 cm^2 when it strikes horizontal ground at the Tropic of Cancer.

2. What is the angle between the sun and the horizon at the Tropic of Cancer at noon on December 21?

____________ °

3. What is the area of horizontal ground covered by a sunray whose cross section is 1 cm^2 on December 21 at the Tropic of Cancer?

____________ cm^2

4. On June 21, 1 cm^2 of horizontal ground at the Tropic of Cancer receives the maximum insolation if the day is clear. Call this 100%. What percent of maximum insolation is received by the same ground on December 21?

____________ %

Step C Calculate the percent of maximum insolation that could be incident at noon on June 21 at the latitude of your school. By answering the following questions before you solve this problem, you will have all the information you need.

5. What is the latitude of your school to the nearest full degree?

______________________________°

6. At what latitude is the sun at the zenith at noon on June 21?

______________________________°

7. What is the difference in latitude between your school and the sun's position at zenith on June 21?

______________________________°

8. How many degrees south of the zenith will the sun be at your school on June 21?

______________________________°

Now go ahead with your diagram on the two parallel lines in the margin.

9. What area will be covered by a sunray 1 cm^2 in cross section at your latitude on June 21?

______________________________cm^2

10. What percent of maximum insolation will you receive?

______________________________%

NAME ____________________ SECTION __________ DATE __________

INVESTIGATION 11-4

Effect of the Tilt of the Earth's Axis on the Geographic Zones

Aim: To discover the effect of the tilt of the earth's axis on the geographic zones

MATERIALS
Ruler 90° triangle, or 3″ x 5″ card Protractor

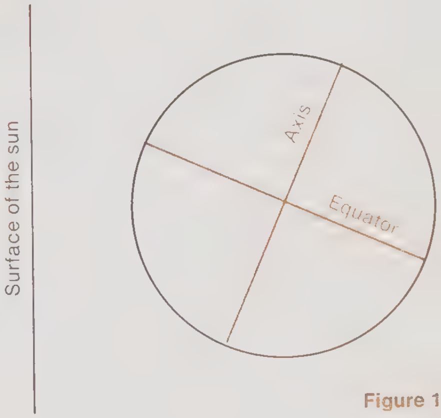


Figure 1

Step A In Figure 1, you will find a circle that represents the earth and a line through it that represents the axis tilted 23½°. The vertical line to the left represents the surface of the sun. Place the triangle so that one edge is on the line that represents the sun's surface and the side at a right angle to that edge is tangent to the earth circle at the north. Put a dot on the earth circle at that point. Do the same at the south polar end. Draw lines across the earth circle perpendicular to the axis line and through each of these dots.

1. What are the names of the lines you have drawn?

____

Step B Continuing on the same figure, draw a line perpendicular to the sun's surface line and through the center of the earth circle, where the equator and the axis cross. From the points where this line intersects the earth circle, draw lines across it that are perpendicular to the axis line.

2. What are the names of these lines?

____

3. Label the geographic zones bounded by the lines.

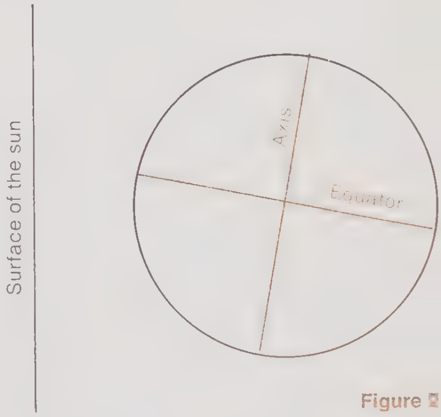


Figure 2

Step C On the earth circle in Figure 2, the axis is tilted only 10°. In the same way that you performed Steps A and B, draw in the Arctic and Antarctic circles and the Tropics of Cancer and Capricorn.

4. What changes have taken place in the extent of the geographic zones?

____

____

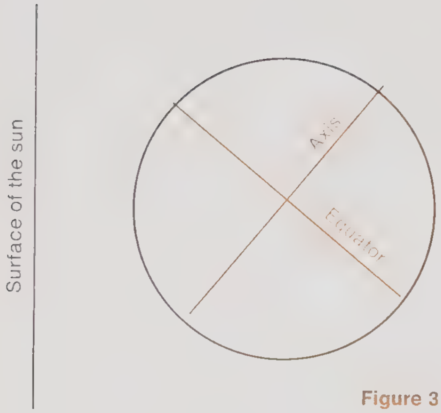


Figure 3

Step D On the earth circle in Figure 3, the axis line is tilted 40°. Draw in the boundaries of the geographic zones, using the method you learned in Steps A and B.

5. What changes have taken place in the extent of the zones?

Step E On the basis of what you observed in Steps C and D, answer the following questions.

6. If the axis of the earth had no tilt at all, what would be the extent of the geographic zones?

7. If the axis of the earth were tilted 45°, what would be the extent of the geographic zones?

8. What would be the situation if the earth's axis were tilted more than 45°?

9. Prove your answer to E-8 with a diagram.

NAME ______________________ SECTION ____________ DATE ____________

INVESTIGATION 12-1

Effect of Color on Absorption of Insolation

Aim: To discover the effect of color upon absorption of insolation

MATERIALS

- Piece of grooved Styrofoam
- Different-colored swatches of the same material, preferably closely woven cotton or wool, *not* nylon (5)
- Thermometers (5)
- Straight pins

Step A Place the thermometers in the grooves in the Styrofoam block. Pin a different-colored cloth over each thermometer. Place the apparatus in direct sunlight.

1. After 5 or 10 minutes, read the temperature of each thermometer and record the information in the table below.

Swatch No.	Color	Temperature
1	________	________°C
2	________	________°C
3	________	________°C
4	________	________°C
5	________	________°C

Step B Examine the data you have accumulated.

2. Under which color cloth was the temperature highest?

____

3. Under which color cloth was the temperature lowest?

____

4. What use do we make of the facts that you discovered?

NAME ____________________ SECTION ________ DATE ________

INVESTIGATION 12-2

Measurement of the Sun's Energy

Aim: To measure energy received from the sun

MATERIALS

Special black calorimeter can
1-hole rubber stopper, No. 11
Thermometer
Watch
Water
Balance and weights

Step A Heat is measured in calories. The most convenient way to measure calories is to record the change in the temperature of water as it absorbs heat. To perform this experiment, you will measure the change in temperature of a weighed amount of water.

1. How would you define a calorie?

____

____

____

____

2. If the temperature of 150 grams of water increased 3°C, how many calories were absorbed by the water?

____________________cal

Step B *Carefully* insert the thermometer through the hole in the rubber stopper. Moisten the inside of the hole and the thermometer. Gently insert the thermometer and twist it as you gently press it into the hole.

3. What is the weight of the calorimeter, stopper, and thermometer to the nearest 0.1 g?

____________________g

4. Fill the calorimeter with water to ½ inch from the top and firmly insert the stopper and thermometer. What is the weight of this apparatus?

____________________g

5. By substracting the weight recorded in **B-3** from that in **B-4**, determine the weight of the water in the calorimeter.

B-4 ________________g

B-3 ________________g

Weight of water used ________________g

Step C You are now ready to perform the investigation. Select a place to put the calorimeter where the sun will shine directly upon it.

6. Read the temperature of the water *before* placing the calorimeter in the sunshine. What is its temperature?

________________°C

7. Place the calorimeter in the sunshine and note on the line below the time when you do this.

________________hr ________________min

8. After 10 minutes, read the temperature of the water again. What is its temperature?

________________°C

9. After 10 more minutes, read the temperature of the water again. What is its temperature?

________________°C

Step D Return your calorimeter to the laboratory.

10. Can you determine by calculating in the chart below the change in the temperature of the water from the data in **C-6**, **C-8**, and **C-9**?

Change in 10 minutes	Change in 20 minutes
C-8 ________________°C	**C-9** ________________°C
C-6 ________________°C	**C-6** ________________°C
Change ________________°C	Change ________________°C

11. From the data in **B-5** and **D-10**, can you determine by

calculating in the table below the number of calories absorbed by the water in 10 and 20 minutes?

10 minutes	20 minutes
B-5 ________ g	**B-5** ________ g
D-10 ________ °C	**D-10** ________ °C
________	________
Calories ________	Calories ________

Step E Study the data that you have accumulated.

12. Can you calculate the number of calories of heat absorbed by the water per minute? Use each of the two time periods you observed.

Calories per minute, 1st 10 minutes ________cal

Calories per minute, 2nd 10 minutes ________cal

Calories per minute, 20 minutes ________cal

13. Why are the three answers in **E-12** slightly different from each other?

14. Can you calculate the cross section of the calorimeter exposed to the sun? Use the metric system and calculate as accurately as you can.

_______________cm^2

15. Calculate the langleys, which are the calories per cm^2, that are received per minute by your calorimeter. How many langleys are received per minute?

_______________ly/min

16. It is estimated that 1.4 ly/min are received at the surface of the earth from the sun, when the sun is directly overhead. Why is your answer to **E-15** lower than this?

____

____

____

____

____

____

____

____

____

____

NAME________________________ SECTION__________ DATE__________

INVESTIGATION 14-1

Making a Cape Cod Barometer

Aim: To make a simple barometer

MATERIALS

Empty bottle
1-hole rubber stopper
Piece of glass tubing, 12″ long; or 1 piece 2″ long,
  1 piece 8″ long, and 1 piece of rubber tubing
  6″ long
Water
Ink or food coloring

Step A A barometer like the one you will build is shown in Figure 1. The first step is to make the bent tube. You can use a single piece of glass tubing and make two bends in it. One bend should be about 2 inches from one end, and the other bend should be far enough away from the first so that the upright tube is clear of the bottle, as shown in the diagram. Another way to make the bent tube is to use two pieces of glass tubing and join them with a piece of rubber tubing.

Step B Insert an arm of the bent tube in the rubber stopper as shown in Figure 1. Wet both the glass and the hole in the stopper. Be careful not to break the glass and cut yourself!

Step C To make the Cape Cod barometer, half-fill the bottle with water. Add enough ink or food coloring to stain the water. Insert the rubber stopper firmly in the mouth of the bottle. Invert the whole apparatus. Water will flow into the bent tube. Hang the apparatus on the wall where it will not be disturbed. If you have used the kind of bent tube made with rubber tubing, fasten the long piece of glass tube to the bottle with a strong rubber band.

Step D Fasten a scale beside the upright glass tube, with the water level in the tube at about the middle of the scale. Record the position of the upper level of the water in the glass tube in the table at the end of the investigation. Each day, record in your table, the level of the water.

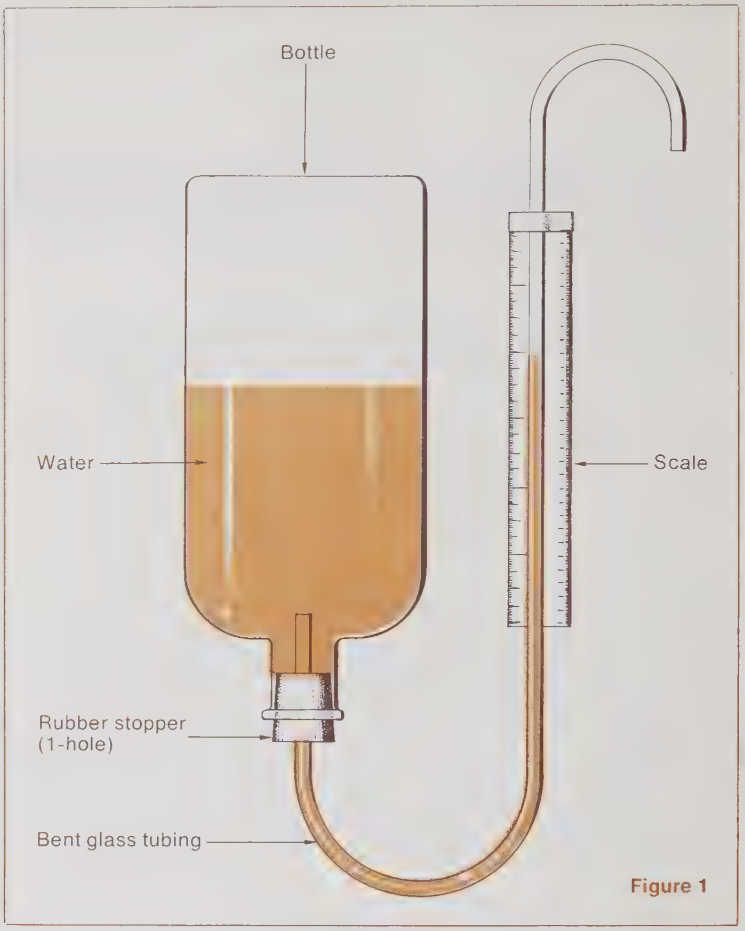


Figure 1

Step E

1. Does the level of the water in the upright tube stay at the same point on the scale from day to day?

2. Why does the water level in the upright tube vary?

3. What causes the water to rise in the upright tube?

4. What causes the water level to drop in the upright tube?

Step F Find the weather reports in the newspapers for the days you observed your own apparatus. Enter the atmospheric pressure for those days in the proper places in your record table.

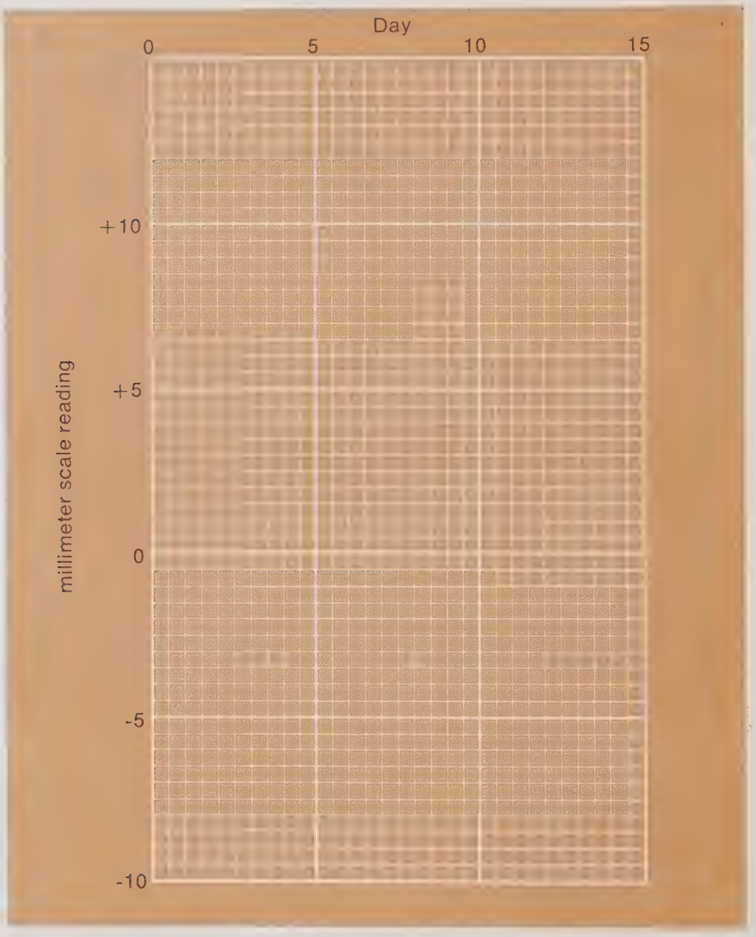
5. Did your apparatus show the same directions of change in atmospheric pressure that were recorded at the weather station?

Step G Plot a graph on the next page that compares your readings of your barometer scale with the pressures recorded by the weather station. From this graph, estimate the readings you should find on your scale that would be comparable to the atmospheric pressures at sea level given below. How do the readings on your barometer compare with those of the weather station?

Atmospheric pressure at sea level	Cape Cod barometer scale
30.5 in	
30.0 in	
29.5 in	

TABLE

Day	Your Readings in mm	Weather Bureau Readings
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		



NAME______________________ SECTION__________ DATE__________

INVESTIGATION 14-2

Making a Wind Gauge

Aim: To make a simple wind gauge

MATERIALS

4″ squares of heavy chipboard, ⅛-inch plywood, light-gauge aluminum, or galvanized iron (2)
Piece of wood, ½″ x 1″ x 15″
Piece of wood, ½″ x 1″ x 12″
Machine bolts and nuts, ¼″ x 1½″ (2)
Washers to fit the bolts (6)
Bolts, ⅛″ x 1½″, with nuts and washers (2)
Bolts, ⅛″ x 1″, with nuts and washers (2)

Step A Examine Figure 1 and assemble the wind gauge apparatus as follows: Attach the scale (one of the 4″ squares) to the support arm. If you wish, you may cut the scale to make a quarter-circle, as shown in Figure 1. Make the wind paddle by bolting the other 4″ square to the swinging arm as shown. Attach the wind paddle to the support arm. Do not tighten the bolt holding the paddle. The paddle must be able to swing freely when you blow against it.

Step B Once the wind gauge is assembled, it must be calibrated. This can be done by comparing it with a standard anemometer or wind gauge. To do this, place the wind gauge you have made near the standard instrument and mark a line on the scale of your gauge along the front edge of the paddle. Read the standard instrument and number the line you have just drawn. Repeat this several times with winds of different velocities. This method is slow because you cannot govern the wind. It will take several days to develop a scale. A faster method is to use an automobile. Select a day when there is little or no wind. Hold your wind gauge out of the window and ask the driver to keep the speed constant at 10 mph, 20 mph, and 30 mph. Mark the deflection of your gauge on the scale for each of these speeds.

Step C The next task is to complete the scale for your wind gauge. To do this, you must have three known points in addition to zero. Zero is when the paddle is hanging in still air in a room. From the known points – 10 mph, 20 mph, and 30 mph – estimate where the intermediate points should

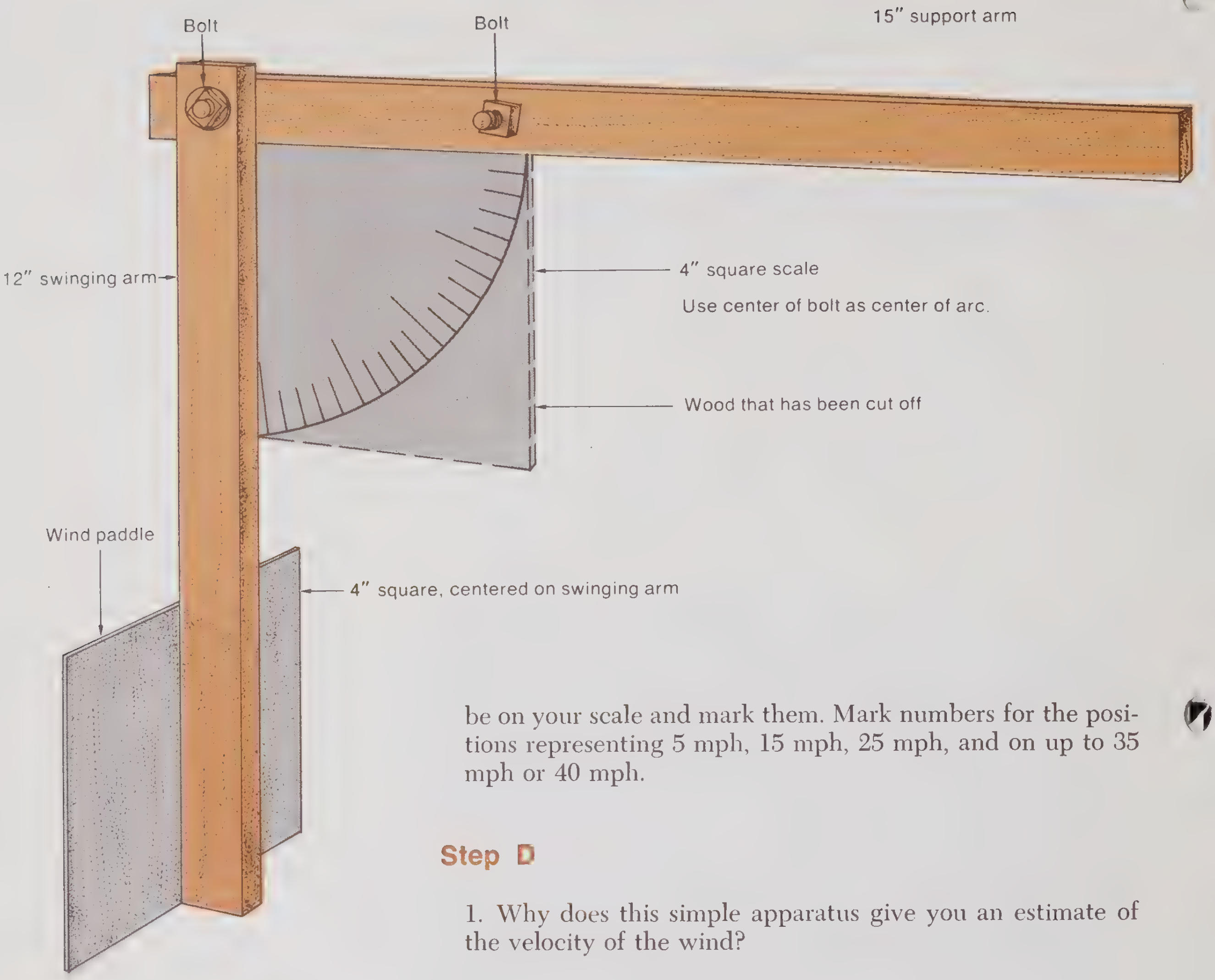

Bolt
Bolt
15″ support arm
12″ swinging arm
4″ square scale
Use center of bolt as center of arc.
Wood that has been cut off
Wind paddle
4″ square, centered on swinging arm

Figure 1

be on your scale and mark them. Mark numbers for the positions representing 5 mph, 15 mph, 25 mph, and on up to 35 mph or 40 mph.

Step D

1. Why does this simple apparatus give you an estimate of the velocity of the wind?

2. Why does your apparatus give you only an estimate of the wind velocity?

3. If you calibrated your instrument at sea level, would your instrument read high, or low, when you used it in the mountains at 6,000 feet?

____

4. Why does altitude affect the accuracy of the reading of any wind-velocity measuring device?

____

____

____

____

NAME______________________ SECTION__________ DATE__________

INVESTIGATION 15-1

Making a Weather Map

Aim: To prepare a weather map from data

Table I includes part of the data collected at 8 A.M. on January 15 at weather stations east of the Rocky Mountains in the United States and southern Canada.

Step A Lay a piece of tracing paper over the map in Figure 1. Clearly mark on the tracing paper (the overlay) three of the corners of the map. You can now precisely replace the overlay if it happens to move. Try not to let it move. The marks you made are called register marks.

TABLE I

Station	Temp. (°F)	Pressure (mc)	Wind Direction	Sky	Station	Temp. (°F)	Pressure (mc)	Wind Direction	Sky
1	−18	1040	NNW	oc	28	25	1011	SW	pt c
2	−25	1042	NNW	cl	29	18	1014	SW	s
3	−23	1034	NNW	pt c	30	10	1023	W	cl
4	−4	1019	NE	cl	31	2	1026	W	cl
5	−10	1014	NW	oc	32	2	1027	NW	s
6	0	1005	NW	oc	33	−6	1017	NE	oc
7	30	998	W	oc	34	8	1023	NE	oc
8	19	1010	SSE	oc	35	20	1023	NW	oc
9	28	1010	SSE	oc	36	22	1024	NW	cl
10	33	1002	SSW	oc	37	25	1017	N	oc
11	25	1002	SW	oc	38	41	1016	NE	oc
12	23	1004	WSW	r	39	42	1015	NE	c
13	21	1004	W	s	40	28	1016	W	c
14	14	1011	NW	oc	41	47	1012	W	c
15	−1	1058	NW	oc	42	49	1010	NW	c
16	−8	1033	NW	s	43	51	1012	WSW	r
17	−15	1037	N	pt c	44	62	1013	SW	c
18	0	1029	N	c	45	60	1012	SSE	c
19	−15	1027	N	c	46	65	1012	S	c
20	10	1026	W	cl	47	61	1011	NW	r
21	9	1019	W	cl	48	67	1011	S	r
22	13	1011	W	s	49	51	1012	N	c
23	38	1006	W	c	50	58	1012	SW	r
24	40	1007	SSE	c	51	50	1013	N	c
25	40	1008	NW	c	52	70	1015	S	pt c
26	47	1009	E	r	53	75	1016	S	cl
27	39	1011	W	c					

c – cloudy   pt c – partly cloudy   cl – clear   r – rain   s – snow   oc – overcast

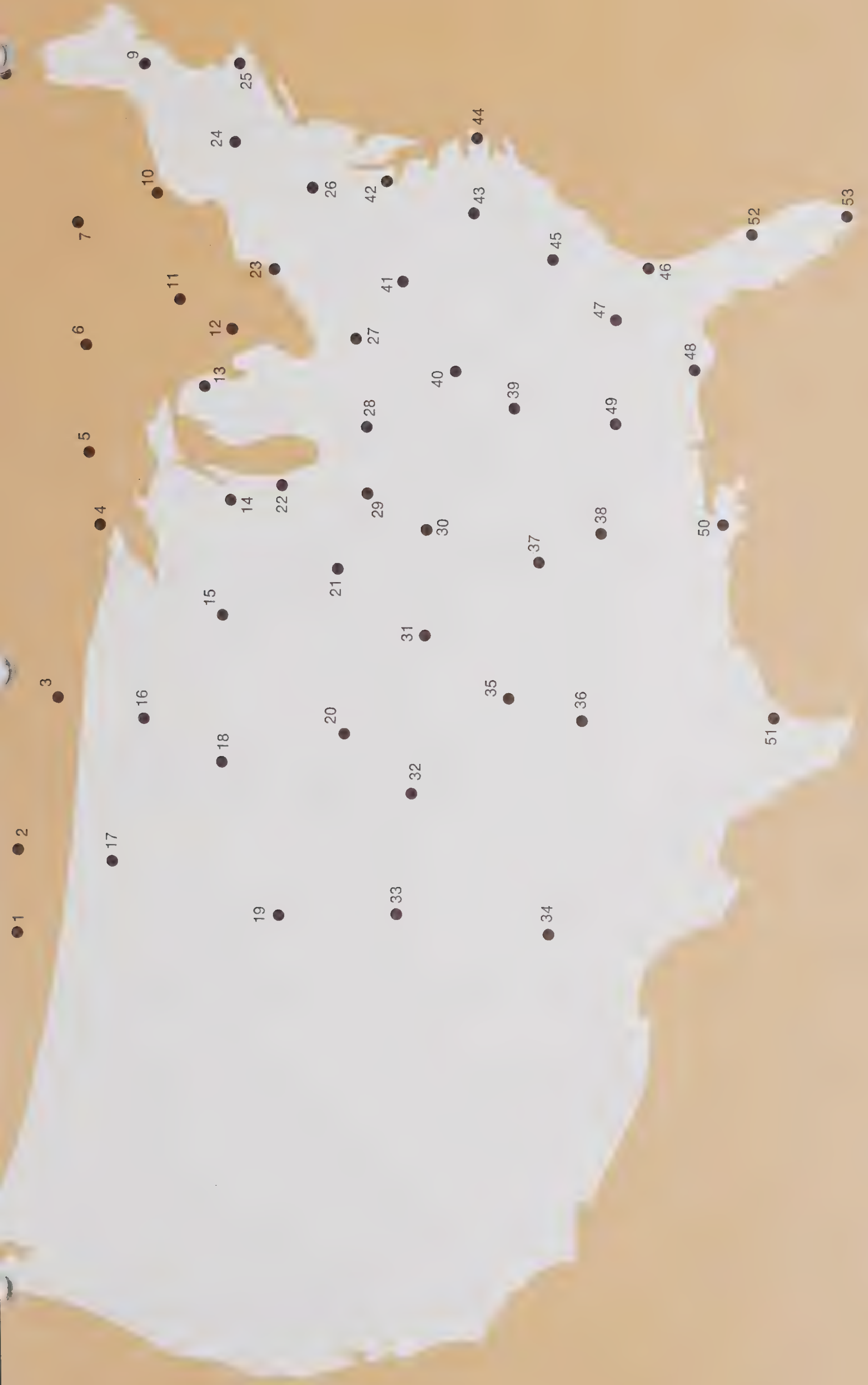
1. Start with station 1, in the northwestern corner of the map. Put the tip of a very sharply pointed pencil in the center of the circle near the number. Draw a short line, not longer than 1/8 inch, from the center of the circle in the direction the wind is blowing according to the data given for the station in Table I. Put the barbs of an arrow at the end of the line you drew. Close to the station circle, write in small print the *last two numbers* of the atmospheric pressure recorded in the table for the station. Repeat this process for each of the 53 stations in the table. You will always find the next number near the last one you used.

2. Again starting in the northwestern corner, draw in the isobars — lines connecting points of the same atmospheric pressure — at each 5-millibar interval. For example: 1040 mb, 1035 mb, 1030 mb, to 1000 mb, the lowest one represented. You will immediately discover that very few stations had pressures in even 5 millibars. Therefore, you will have to decide from all the stations in a small area where to draw the lines between stations. For example: the 1040-mb line will pass a little closer to the station with pressure 1042 than to the one directly south of it, where the pressure was 1037. Most of the lines will run off your map. Label each line with its pressure value at both ends where the line goes off the map. Only two or three of the isobars will close. For these, leave a break in your line for the label.

3. Study the pattern of the isobars. Label any lows and highs that you believe existed. Use both the isobars and the wind arrows to help you make your decisions.

4. At which station (or stations) do you think the strongest winds were recorded?

5. At which station (or stations) do you think there were only light winds?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53

6. Remember that this is a record for January. In what way does the arrangement of isobars suggest that a polar outbreak has occurred?

Step B To test your answer to **A-6**, it will be necessary to prepare a map of the isotherms, lines that connect places that have the same temperature readings. Use a second sheet of tracing paper as an overlay. Register it at the same corners you used in Step A.

7. Put a dot in each of the station circles as you enter the temperature recorded in the table for that station. Make your numbers clear but small. Use a very sharp pencil. Start in the northwestern corner, as you did in Step A.

8. Draw in the isotherms, using the same technique you used for the isobars.

9. Place your overlay for temperature over the one for pressure, using the register marks. Does the distribution of temperatures support your answer for **A-6**? In which region is this particularly evident.

Step C Here are tables of 8 A.M., EST, temperatures for several groups of stations.

TABLE II

	Great Plains		Eastern Midwest		Opposite sides of Appalachian Mts.	
	Station		Station		Station	
	32	35	28	40	23	26
Jan. 14	10	33	40	53	43	45
Jan. 15	02	20	25	28	38	47
Jan. 16	−10	10	20	33	20	30

10. Station 32 is not far north of 35, Station 28 is not far north of 40, Station 23 is west of the mountains and 26 east of them. On which date did the cold front reach each station?

Station 32 ________________ 35 ________________

28 ________________ 40 ________________

23 ________________ 26 ________________

11. In what direction was the front moving?

12. Did the Appalachian Mountains act as a barrier to the movement of the cP air?

TABLE III

	Gulf Coast			Atlantic Coast		
	Station			Station		
	50	51	48	25	44	52
Jan. 14	63	62	69	40	65	68
Jan. 15	58	50	67	40	62	70
Jan. 16	40	31	50	39	50	65

13. On what day did the front reach the Gulf Coast?

14. Does this support your answer to **A-6**? Why?

15. Was the effect of the front as severe on the Atlantic Coast as on the Gulf Coast and in the Midwest? Why?

NAME______________________ SECTION__________ DATE__________

Keeping a Weather Record

Aim: To prepare and keep a weather record

Before scientists invented the various instruments that are used to measure features of the weather, many people kept long and accurate accounts of local weather for their community. You can do this, too. Although weather instruments are nice to have, you do not need any to keep such a record. What you do have to do is observe accurately and record your observations faithfully. These observations should be made at the same time each day – while walking to school in the morning or while waiting for the school bus. These are the features you should observe and record:

1. Is the temperature hot, warm, cool, cold, or below freezing?

2. How much of the sky is covered with clouds?

3. From which direction is the wind blowing?

4. How strong is the wind? For this, use the U. S. Weather Bureau terms:

Calm – no wind at all.

Light – leaves flutter and you can feel wind on your face.

Gentle – leaves and twigs on trees move; flags flap.

Moderate – raises dust and loose paper.

Strong – you have some difficulty walking and have to lean into the wind.

Gale – you don't go out! Trees sway. Small twigs break from trees.

5. Is there no precipitation, or is there fog, drizzle, rain, heavy rain, snow, sleet, hail, or thunderstorms?

The observations you make should be written down in the table on the next page.

Date	Temperature	Sky	Wind direction	Wind strength	Precipitation	Other notes

NAME____ SECTION__________ DATE__________

INVESTIGATION 17-1

Work Capacity Available in a Stream

Aim: To calculate the amount of available energy in a stream

This is a pencil-and-paper investigation. In it you will learn how scientists approach certain kinds of problems that are very difficult to solve through observation and experimentation. We will use an imaginary stream that has a gradient of 30 feet per mile and a uniform velocity of 5 miles per hour throughout the test mile. This stream is delivering 200 cubic feet of water per second. Let us examine some of the things we know about the stream.

1. Since the velocity is uniform throughout the test mile, what happens to the energy made available as the water is lowered 30 feet per mile?

____

____

2. The force of moving water can do work. The formula used to calculate force is $f = m\,v^2$. Since we are using the English system with this investigation, in what units will m (mass) and v (velocity) be measured?

____

____

____

3. Since we need to know the velocity of the water in feet per second, how do we change it from miles per hour?

____

____ft/sec

4. Water weighs 62½ pounds per cubic foot. What weight of water passes a point in one second?

____

____lb/sec

5. What is the force exerted by the moving water?

____

____ft-lb/sec^2

6. Does this force change as the water flows through the test mile? Why?

7. What is the effect of gravity on water flowing down a slope where there is no friction?

8. Does gravity effectively change the velocity of the stream we are considering?

9. What is the effect of friction on water flowing down a slope?

10. Did friction make any change in the initial velocity of the stream being studied?

11. What happened to the increase in force caused by the gravitational acceleration in our stream?

12. What is the rate of acceleration for our stream? (See Section 17-1 in your textbook for an explanation of how to calculate acceleration.)

__________ft/sec^2

13. Since there is no change in velocity in our stream, the accelerations (positive for gravity and negative for friction) exactly balance each other. What is the amount of force provided by the acceleration of our stream? See **A-2** for a clue.)

____

____________________________________ ft^2-lb/sec^4

14. How much work is the stream doing to overcome friction at a particular point each second?

____________________ ft-lb

15. From **5** and **14** you can estimate the total power of the stream flowing by a point. What is it?

____________________________________ ft-lb

16. What part of the stream's total power is used to overcome friction?

____________________________________ %

NAME ______________________ SECTION____ DATE____________

Isostasy

Aim: To demonstrate isostasy

MATERIALS

- Pan, 9″ x 12″ x 2″
- 1-qt plastic bag
- Elastic band
- Pieces of wood, 8″ x 5″ x 1″ (2)
- Sand, gravel, or small stones
- Water
- Pan partly filled with gelled gelatin
- Piece of plastic wrap
- Small bucket of dry sand
- 3″ x 5″ card

Step A Fill the plastic bag half full of water and seal it by twisting the top and winding an elastic band around it. Place the bag in the pan, with the sealed portion at one end. Put the two blocks of wood alongside one another on top of the bag.

1. Do the two blocks of wood float evenly on the bag? If not, note the difference in elevation of the upper surfaces.

____

2. Load both blocks of wood with sand, gravel, or small stones so that the top surfaces of the blocks are even.

3. Remove the material from the top of one block and place it on the other. What happens?

____

____

4. What action that occurs on the earth is demonstrated in **A-3**?

____

____

____

Step B Remove the blocks of wood and brush them off. Replace the blocks of wood and note their relative vertical positions.

5. Load one of the blocks with several ice cubes. What happens to the other block?

6. Set your investigation aside for a while, until the ice melts.

7. After the ice has melted, observe the relative positions of the blocks of wood. What has happened?

8. What geologic action have you imitated in **B-5** through **B-7**?

Step C Make a second demonstration of this principle in the following way. Cover the gelled gelatin in the pan with the plastic wrap so that there is a border of the thin plastic overlapping all edges of the pan. Pour sand into the pan until it is uniformly ½″ to ¾″ deep. Smooth the surface of the sand with a 3″ x 5″ card.

9. Gently pour sand into one end of the pan to form a "hill" about two inches high. What happens?

10. When you built the "hill," what caused the gelatin layer underneath to sink?

11. What raised the sand at the end of the pan opposite the "hill"?

12. What caused the action you saw?

13. Build another "hill" at the end of the pan opposite the first hill. What happened when you built the hill?

14. Use the 3″ x 5″ card to make the sand surface level again. See if you can again establish a "stable" situation.

15. What condition brings around a stable situation?

NAME ____________________ SECTION ________ DATE ________

Convection Currents

Aim: To study convection currents

MATERIALS
1-liter beaker
Bunsen burner, tripod, asbestos gauze mat
Water
Ink
Pipette

Step A Place the beaker on the asbestos gauze on the tripod. Fill the beaker ⅔ to ¾ full of water. With the pipette, carefully introduce about 10 ml of ink into the bottom of the beaker of water.

1. Why does the ink form a layer at the bottom of the beaker?

____

____

____

Step B Light the Bunsen burner and place it underneath the beaker.

2. What happens as soon as you place the Bunsen burner under the beaker?

____

____

3. What happens as the flame continues to burn under the beaker?

____

____

____

____

4. How do you explain your observation in **B-3**?

5. What happens in the beaker after heating it a few minutes longer?

6. What have you produced in the beaker of water?

NAME________________________ SECTION__________ DATE__________

INVESTIGATION 22-2

How Does Salt Affect Water?

Aim: To discover what salt does to water

MATERIALS	
400-ml beaker	Wire
Copper strips, 1″ x 6″ (2)	Table salt (NaCl), 10 g
Zinc strip, 1″ x 6″	Distilled water, 500 ml
Voltmeter	Balance and weights
Battery, 1.5 volt	100-ml graduated cylinder

Step A In this step you will measure a few of the properties of water. Since you want pure water, you will have to use water that has been distilled to rid it of any impurities.

1. Weigh the 400-ml beaker as accurately as you can, at least to the nearest 0.1 g. What is the weight of the beaker?

______________g

2. With the graduated cylinder, measure 100 ml of distilled water and pour it into the weighed beaker. Be careful not to spill any water. Then weigh the beaker with the water as accurately as you can. What is the combined weight of the beaker and the water?

______________g

3. Compare the weight of the empty beaker with that of the beaker filled with water. Is the difference in weight what you expected it to be? Explain your reasoning.

4. Weight out approximately 3.5 grams of table salt. What is the exact weight of the salt, to the nearest fraction of a gram?

______________g

5. Add this salt to the water in the beaker and gently swirl it until it is completely dissolved. What is the weight of the beaker with its salty water?

______________g

6. Is the weight you measured in **A-5** exactly the sum of the weights in **A-2** and **A-4**? Why?

____

____

____

____

7. Pour the salty water into the graduated cylinder. What is the volume of the salty water? (Save this solution for Step D.)

______________ml

8. Explain the difference, if any, between the measurement in **A-7** and the 100 ml of distilled water you used in **A-2.**

____

____

9. What is your estimate of the density of your salt water?

______________g/cm^3

10. What effect did the addition of salt have upon the density of the water?

____

____

____

____

____

____

Step B Carefully rinse the 400-ml beaker with two changes of tap water and then with some distilled water. Dry the inside of the beaker with a paper towel. Arrange the two copper electrodes as shown in Figure 1. Be absolutely sure that the electrodes do not touch one another.

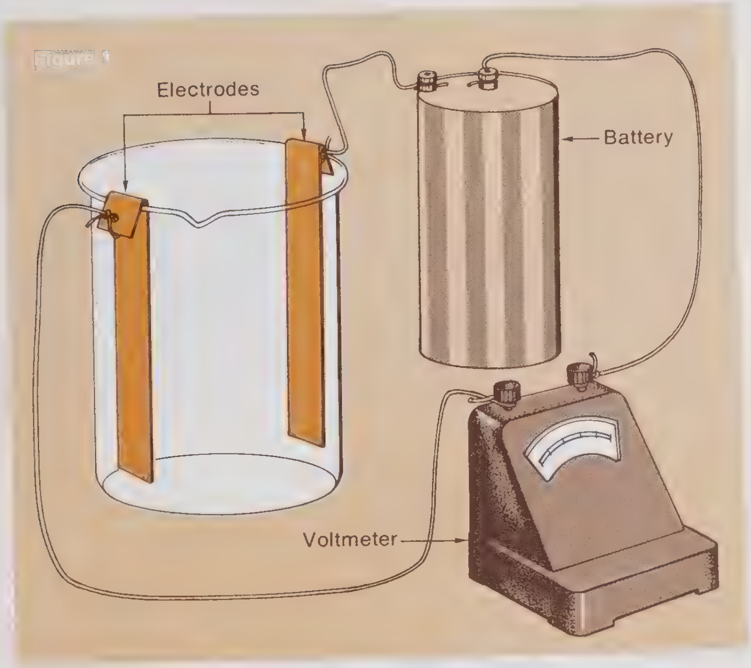


Figure 1

11. Read and record the position of the needle on your voltmeter.

______________volts

12. Add about 100 ml of distilled water to the beaker. What is the voltmeter reading?

______________volts

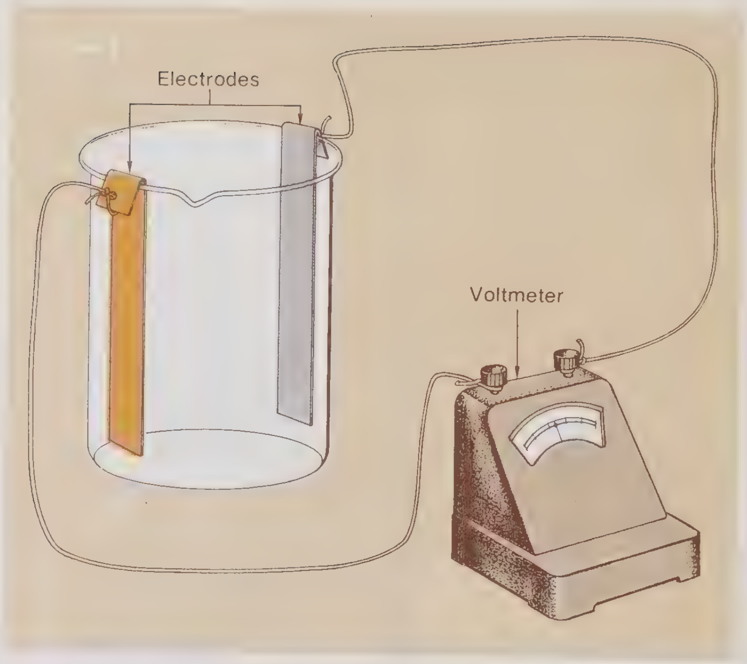
13. Does the distilled water conduct an electric current?

____

Step C Replace one of the copper electrodes with a zinc one. Remove the battery from the circuit and connect the voltmeter directly to the electrodes as shown in Figure 2.

14. Lower the electrodes into the distilled water in the beaker. What is the voltmeter reading?

______________volts



15. Did the distilled water produce an electric current in the presence of two different metal electrodes?

____

Step D Use the same circuit that you used in Step B.

16. After placing the electrodes in the beaker, add the salt water you saved in the graduated cylinder. What does the voltmeter read?

____________________volts

17. How do pure water and salt water differ in their behavior in Steps B and D?

____

____

____

____

Step E Use the same circuit you used in Step C.

18. After replacing the electrodes in the salt water, what is the voltmeter reading?

____________________volts

19. How do pure water and salt water differ in their behavior in Steps C and E?

20. From what you learned in this investigation, how would you explain why salty seawater corrodes metals more rapidly than does fresh water?

NAME________________ SECTION__________ DATE__________

INVESTIGATION 26-1

Measuring the Force of Gravity

Aim: To measure the force of gravity

MATERIALS

- Pendulum bob
- Ring stand
- Stopwatch
- String
- Yardstick

Step A You will work in groups for this investigation. Set up the apparatus as shown in Figure 1, tying the string to the edge of the ring so that the pendulum is 2 feet in length and can swing freely. Set your textbook on the back of the ring stand to stabilize it. Hold the pendulum bob high and let it drop.

1. Does it accelerate as it drops? ______________

2. What force causes it to accelerate? ______________

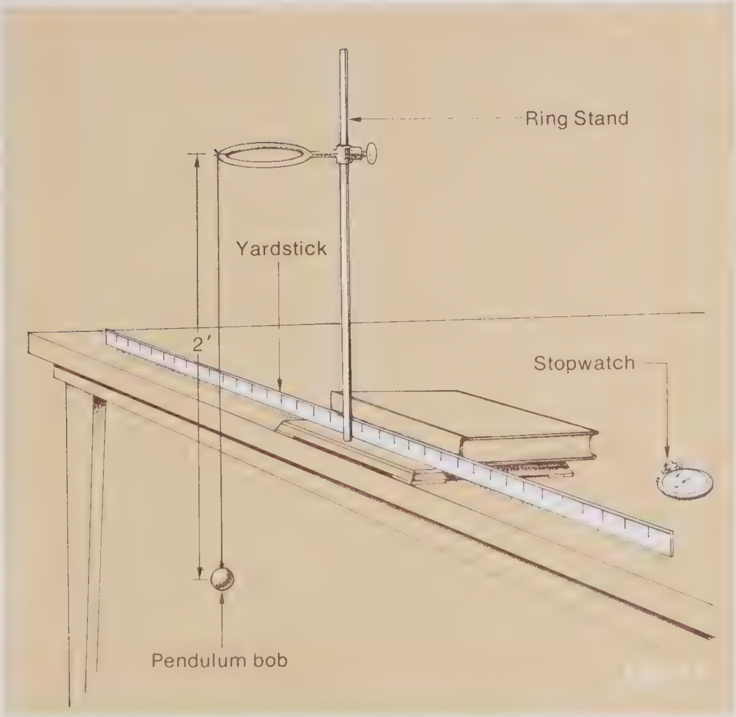


Figure 1

Step B Now you will measure the force of gravity in your location.

The pendulum swings in a complete cycle when it goes from position 1 to position 2 and back to position 1 again, as labeled in Figure 2. Hold the pendulum bob at an angle of approximately 15° from the ring stand, as shown in Figure 2. The timer should practice starting the watch at the exact moment when his lab partner drops the pendulum bob.

3. Time 5 cycles of the pendulum. How many seconds does this take?

________________sec

4. To calculate the force of gravity, use the following formula: $T = 2\pi \frac{l}{g}$, where T = time for one cycle, l = length of pendulum, and g = gravity. Make the appropriate substitutions in the formula and solve for g. Remember to keep the time in seconds and the distance in feet. Make your calculations to two decimal places. (Hint: Square the terms on both sides of the equation to eliminate the square root.)

$g =$ ______________ft/sec^2

Step C Repeat this investigation, using different pendulum lengths and timing various numbers of cycles.

5. Does the force of gravity vary with different pendulum lengths?

6. Does it vary when you time different numbers of cycles?

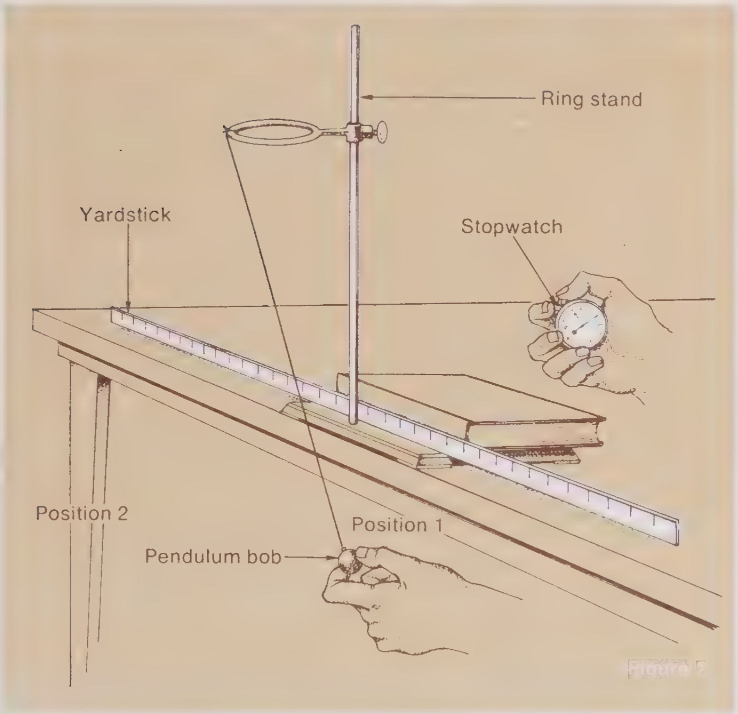


Figure 2

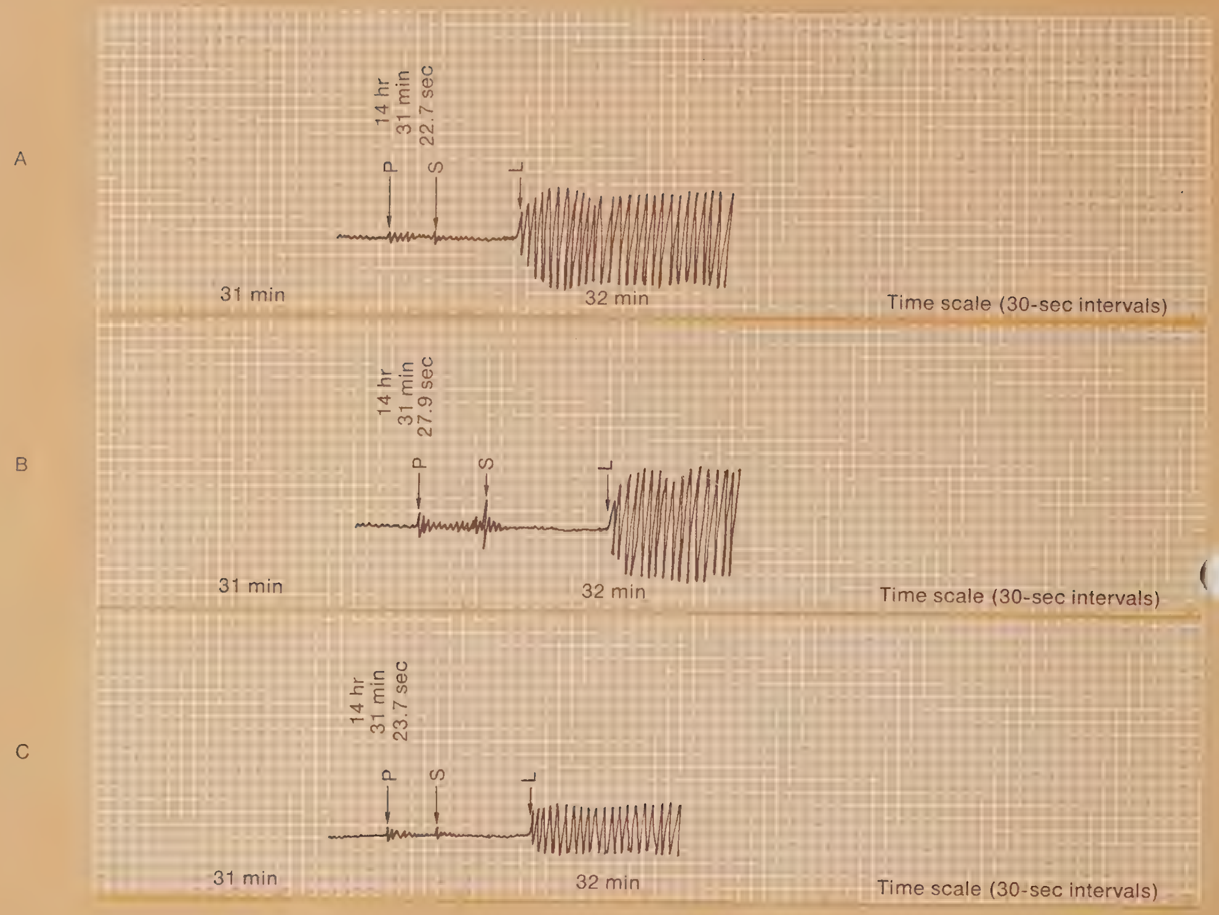

A
P
S
L
14 hr
31 min
22.7 sec
31 min
32 min
Time scale (30-sec intervals)
B
P
S
L
14 hr
31 min
27.9 sec
31 min
32 min
Time scale (30-sec intervals)
C
P
S
L
14 hr
31 min
23.7 sec
31 min
32 min
Time scale (30-sec intervals)

Figure 1

NAME ______________________ SECTION __________ DATE __________

INVESTIGATION 29-1

Locating an Epicenter

Aim: To locate the epicenter of an earthquake

MATERIALS
Millimeter scale Pencil compass

Step A Figure 1 represents the seismographic record of an earthquake as recorded at three separate stations. You will find the first indications of P-, S-, and L-waves recorded.

1. Using the millimeter scale, determine the difference in the time of arrival of the P- and S-waves at each of the three stations, and record this information in the table below.

Station	Time Intervals
A	sec
B	sec
C	sec

Step B When the time interval between the arrival of the P-wave and the S-wave is known, the distance to the epicenter can be estimated. For a nearby earthquake, the distance estimate is made by multiplying the time interval by 8.9 km/sec.

2. Estimate the distance between each station and the epicenter, and fill in this information in the table that follows.

Station	Distance
A	km
B	km
C	km

Using an alternate method, it is possible to calculate the time when an earthquake occurred from the difference in arrival times of the P-wave and the S-wave. Once the time is known, the distance from the station to the epicenter can be calculated. The equation for estimating how long the earthquake wave traveled before it reached the station is this:

$$5.8\,t = 3.5\,(t \div \triangle) \tag{1}$$

when 5.8 km/sec is the speed of the P-wave, 3.5 is the speed of the S-wave, and $\triangle$ is the difference in the time of the waves' arrival at the station. Equation (1) can be transformed by algebra into a more easily solved form by these steps:

$$5.8\,t = 3.5\,t \div 3.5\,\triangle \tag{2}$$

$$5.8\,t - 3.5\,t = 3.5\,\triangle \tag{3}$$

$$2.3\,t = 3.5\,\triangle \tag{4}$$

$$t = 3.5\,\triangle/2.3 \tag{5}$$

3. Solve for t for each of the three stations, using the differences you found in **A-1**. Fill in the information in the table below.

Station	P-wave travel time to station
A	sec
B	sec
C	sec

4. Using the rate 5.8 km/sec and the times you found in **B-3**, estimate the distance to the epicenter of the earthquake from each station, and record it below.

Station	Distance to epicenter
A	km
B	km
C	km

Step C Once the distance to the epicenter is known, its location can be estimated graphically. In Figure 2 you will find each of the three observation stations marked with its proper letter. With a compass set for the proper distance between the epicenter and Station A, draw a circle with

Station A as the center. Do this for each of the three stations.

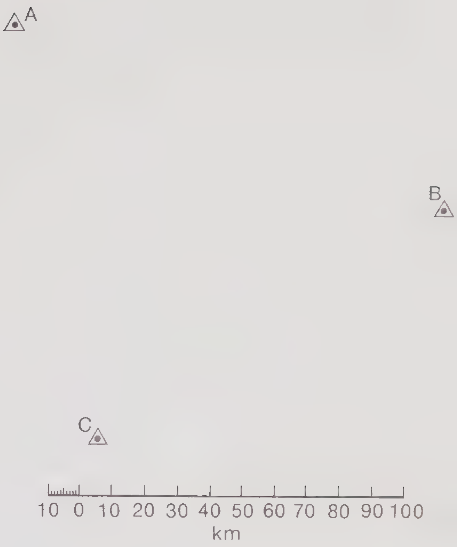


Figure 2

5. Why do the three arcs not intersect at one point?

6. Place a dot in the middle of the "triangle of error." Call this the epicenter. Measure the distance from the epicenter to each station and record it below.

Station	To epicenter
A	km
B	km
C	km

7. From the speed of P-wave (5.8 km/sec) and the distance you measured and recorded in **C-6**, calculate how long it took the wave to travel from the epicenter to each of the three stations, and record it below.

To station	Travel time
A	sec
B	sec
C	sec

8. From the data on the seismograms and the travel times you calculated for **C-7**, estimate when the earthquake occurred in relation to each station, and record this information in the following table.

Station	Time of Earthquake		
A	hr	min	sec
B	hr	min	sec
C	hr	min	sec

9. Take the average of the three times in **C-8**. This is the best estimate of when the earthquake occurred. When did it occur?

______hr ______min ______sec

NAME ______________________ SECTION __________ DATE __________

INVESTIGATION 30-1

Refraction of Light Rays

Aim: To study refraction

MATERIALS

Beaker of water	Piece of white paper
Pencil	Ruler
Piece of plate glass (¼″ thick)	Common pins (3)

Step A Refraction is a wave phenomenon. The same rules govern refraction of elastic waves in rocks that govern refraction of light waves. It is much easier to study light waves than elastic waves. What we learn from light waves, we can apply to elastic waves. Hold a pencil diagonally in a beaker of water. Look directly down upon it.

1. What apparent change do you observe in the shape of the pencil?

2. Through what medium did the light rays pass that let you see the part of the pencil out of the water?

3. Through what did the light rays pass that allowed you to see the part of the pencil under water?

4. In reference to **A-3**, where did the apparent bending of the pencil take place?

5. Are the media involved in seeing the pencil under water different in density? Which is denser?

6. Where did the apparent bending of the pencil take place with respect to densities?

Step B Place the piece of plate glass flat on a piece of white paper. Place a common pin upright at the edge of the glass that is away from you. Place another pin upright about two inches from the first pin and beyond it so a line through the pins strikes the edge of the glass at other than a right angle. Look through the glass edgewise. Move your head to align the images of the two pins. Place a third pin upright at the edge of the glass nearer you so it is in line with the *image* of the first two pins aligned by sighting. Carefully remove the piece of glass. Draw straight lines from the first pin to the second and from the third pin to the first.

7. Do the two lines you drew form a straight line?

8. If you continue the first line you drew, between pin 1 and pin 2, does it pass to the left, or right, of pin 3?

9. What caused the path of the light ray from pin 1 to pin 2 to bend to pin 3?

Step C Repeat Step B several times. Each time, have the line between pin 1 and pin 2 at a different angle to the edge of the glass. Include one experiment with that line perpendicular to the edge and at least one experiment on each side of the perpendicular. Study your results.

10. Was the light ray bent when the line from pin 1 to pin 2 was perpendicular to the edge of the glass?

11. Was the light ray bent when the line from pin 1 to pin 2 was not perpendicular to the edge of the glass?

12. When the light ray was bent, did it bend toward or away from the line perpendicular to the edge of the glass?

13. When the light ray traveled from pin 2 to pin 3, did it pass from more dense to less dense, or from less dense to more dense, material?

14. What would happen to a light ray passing from glass into air?

Step D Examine Figure 1. It represents a beam of waves moving at an angle through an interface, a discontinuity that occurs between a less dense and a more dense medium. The dashed line is perpendicular to the interface. The line with arrow points on it is the path of a ray. The parallel lines are wave fronts advancing at a uniform rate per second. Notice that the path of the ray always is perpendicular to the wave front.

15. Which medium, A or B, is the denser? Why?

16. Study the spacing between the wave fronts. Remember that the spaces represent uniform intervals of time. In which medium is the wave front moving forward most rapidly? Why?

17. Study your answers to **D-15** and **D-16**. What is the effect of density upon the speed at which a wave front moves through a medium?

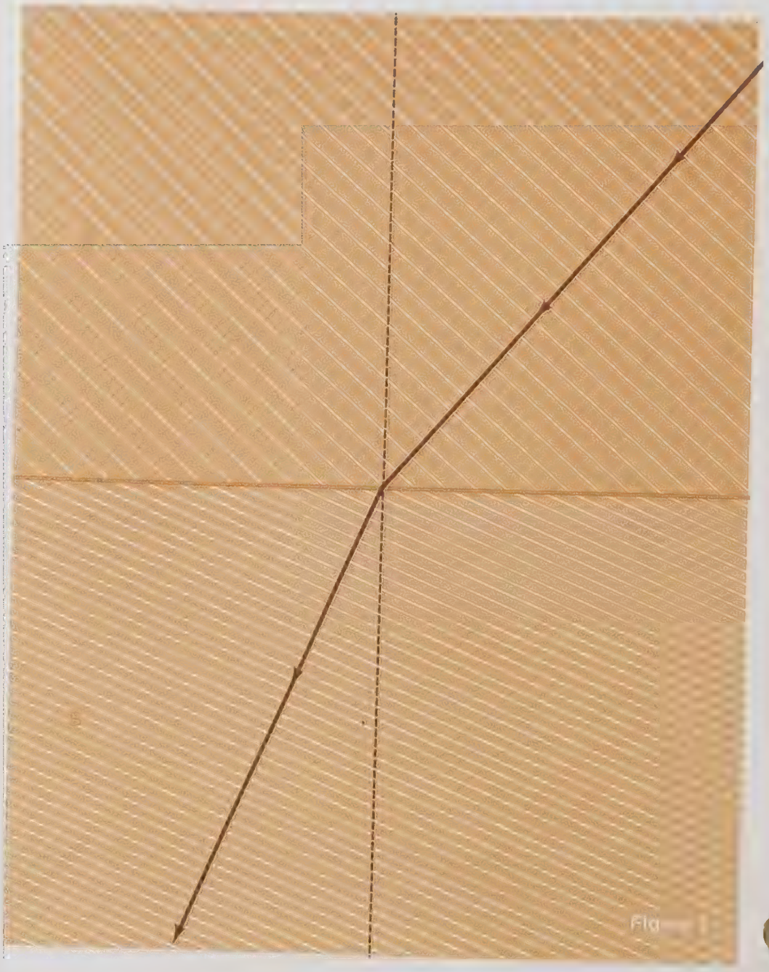


Figure 1

NAME ____________ SECTION ______ DATE ______

INVESTIGATION 31-1

Impact Craters

Aim: To study the shapes of impact craters

MATERIALS
Sand box, 12″ x 12″ x 3″ Dry, clean sand (enough to fill the box) Large steel ball bearings (3 or 4)

Step A Fill the sand box to within an inch of the top with clean, dry sand. Smooth the surface with your hand, a ruler, or a piece of cardboard. Place the box on the floor and, standing on a chair or stool, drop a ball bearing into the box. Observe what happened at the point of impact.

1. What is the shape of the crater? ____________

2. What has happened to the surface of the sand immediately surrounding the crater?

____

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3. Draw a cross section of the crater and its immediate surroundings.

4. Repeat the investigation, having a partner drop the ball bearing as you observe closely what happens. What did you observe?

____

Step B Alternate with your partner in throwing the ball bearing at the sand and observing the impact. Start by throwing at an angle that is close to the perpendicular and with each throw increase the angle from the perpendicular.

5. What change in the shape of the crater did you observe when the angle of throw was less than 45° from the perpendicular?

6. How did the shape of the rim change as the angle of incidence increased from 0° (perpendicular) to 45°?

7. When the angle of the throw was greater than 45° from the perpendicular, how did the shape of the crater change?

8. As the crater shape became noticeably elliptic, what happened to the cross section of the rim?

Step C Meteor craters are impact craters formed in much the same way you made craters in the sand.

9. Almost all known meteor craters are circular, or very nearly circular, in shape. Does this mean that the meteor came straight down to earth in a line perpendicular to the surface? Why?

10. All known meteor craters have a noticeable rim that rises above the surrounding countryside. How is that rim formed, and what was the source of the material that composes the rim?

NAME______________________________ SECTION__________ DATE__________

INVESTIGATION 32-1

Magnetism

Aim: To reveal the magnetic field around magnets

MATERIALS
Bar magnet Horseshoe magnet Piece of paper Container of fine quartz sand Container of fine iron filings

Step A Place the bar magnet flat on your desk. Cover it with a sheet of paper so that the magnet is more or less under the middle of the sheet. Lightly sprinkle fine quartz sand on the paper over and around the magnet.

1. What do you observe?

____

____

____

2. Carefully lift the paper from the magnet and pour the sand back into its container.

Step B Arrange the magnet and paper as you did for Step A. Lightly sprinkle fine iron filings on the paper.

3. What do you observe?

____

____

____

____

4. Where is the pattern most strongly developed?

____

____

5. What does this indicate about the strength of the magnet?

6. Draw a diagram of the arrangement of the iron filings.

7. Carefully lift the paper from the magnet and return the filings to their container.

Step C Repeat Step B, using the horseshoe magnet.

8. Where is the pattern of iron filings most strongly developed?

9. Make a diagram of the pattern formed.

10. How does the pattern in Step C differ from that in Step B?

11. In which step does the pattern more closely resemble what you know of the earth's magnetic field?

12. Carefully lift the paper and return the filings to the proper container.

NAME ____________________ SECTION __________ DATE __________

INVESTIGATION 32-2

Effect of Heat on Magnetism

Aim: To determine the effect of intense heat on magnetism

MATERIALS

Nail, 10d iron
A solenoid, or 10 feet of silk- or lacquer-insulated
  14-gauge copper wire
Laboratory forceps
Iron filings, or a few very small iron tacks
Small magnetic compass
Bunsen burner
"D" battery

Step A

1. Test the iron nail for magnetism, using the materials given to you. How can you tell the nail is not magnetized?

2. Place the nail in the solenoid and close the circuit through it for a few seconds, or wrap the insulated copper wire around the nail as neatly as you can. Attach one end of the wire to one terminal of the "D" battery and leave the other end free. Place the wrapped nail on a level surface. Hold the free end of the wire against the unused terminal of the battery for a few seconds.

3. Remove the nail from the solenoid, or slip it out of the coil of wire. Repeat the tests you used in **A-1**. How do you explain the differences you observe?

Step B Light the Bunsen burner and adjust it to get a clear blue flame. Hold the nail in the forceps and heat the nail to redness in the upper blue cone of the Bunsen flame.

4. Repeat the test you used in **A-1**. How do you explain the effects that you observe?

5. Would you expect molten iron to be magnetic? Why?

6. Would you expect the outer core of the earth to be magnetic? Why?

INVESTIGATION 32-3

Lines of Magnetic Force Around an Electrified Wire

Aim: To demonstrate the lines of magnetic force around an electrified wire

MATERIALS

- Dry cell
- Bare copper wire, 12-gauge
- Thin cardboard
- Fine iron filings

Step A Arrange your apparatus as shown in Figure 1. Lightly sprinkle some iron filings on the cardboard around the wire.

1. Are the iron filings in an orderly pattern or are they randomly distributed?

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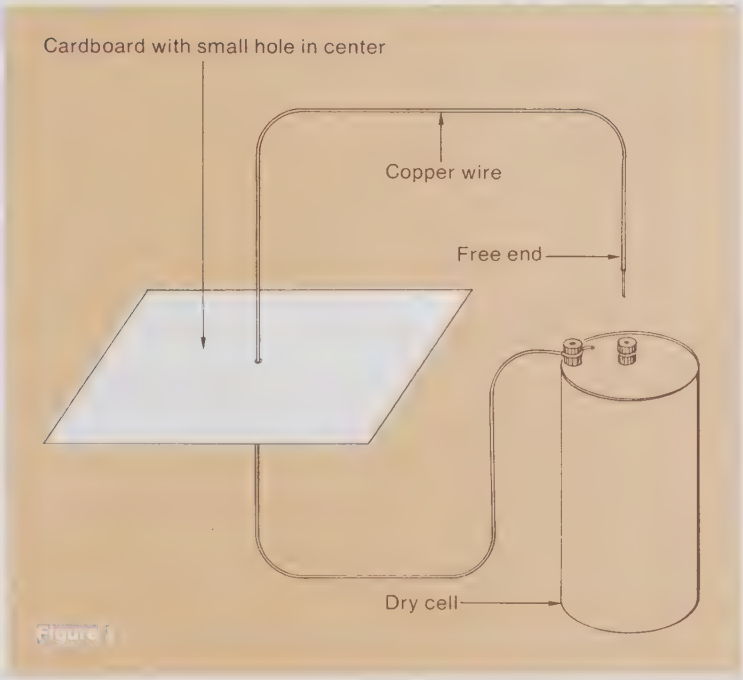

Figure 1

Step B Touch the free end of the wire to the middle terminal of the battery. Gently tap the cardboard. Remove the free end of the wire from the middle terminal.

2. What happened to the iron filings?

____

____

____

3. What caused the action you noted in **B-2**?

____

____

____

Step C Gently tap the cardboard.

4. What happened?

____

____

____

5. How were the conditions in Step B different from those in Step C?

____

____

____

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____

6. What do you conclude from this investigation?

____

____

NAME ____________________ SECTION ________ DATE ________

INVESTIGATION 33-1

Phases of the Moon

Aim: To investigate the phases of the moon

MATERIALS
Ping-Pong ball
Straight pin
Flashlight
Household cement

Step A Put a little household cement on the head of the pin. Press the head of the pin against the Ping-Pong ball so that when the cement hardens, the pin will be a handle for the ball. Darken the room. Consider the light from the flashlight to be light from the sun and the Ping-Pong ball to be the moon. You are an observer and you represent the earth.

1. Stand about 6 feet from the flashlight, which is directed toward you and illuminated. Hold the Ping-Pong ball by its "handle" at arm's length so that you are at the right angle of a triangle made by you, the "sun," and the "moon." How much of the "moon" is illuminated? How much of the illuminated "moon" do you see?

____

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____

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2. Holding the "moon" at arm's length, slowly turn through 360°. What change takes place in the area of the surface of the "moon" that is illuminated?

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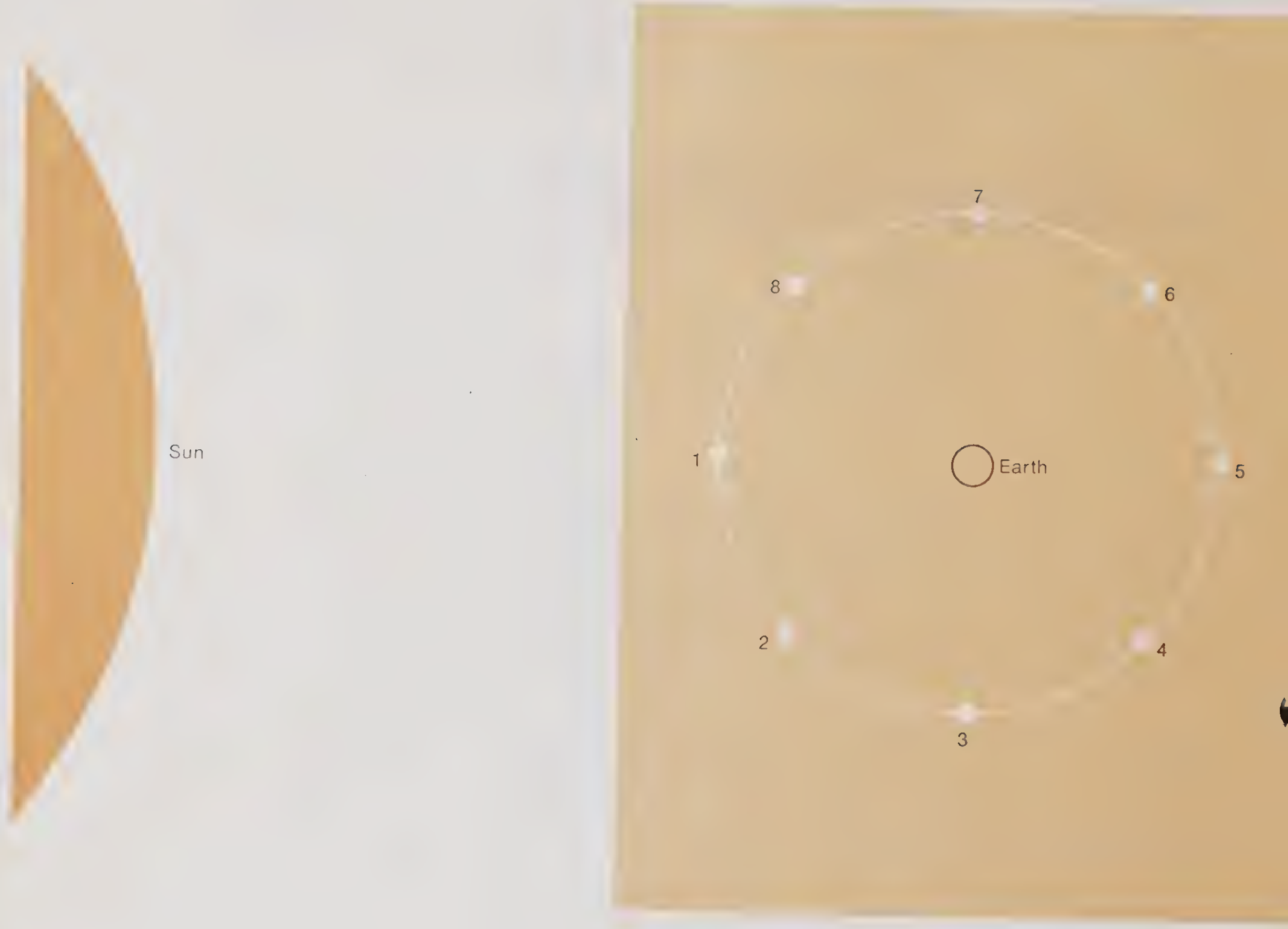
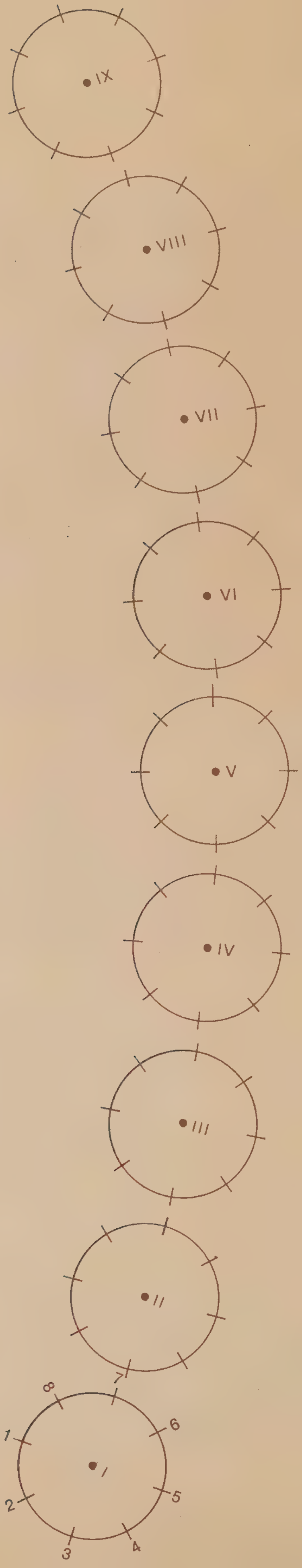


3. In **A-2**, what changes did you observe in the size of the portion of the illuminated surface of the "moon" that you saw, considering yourself as the earth?

Step B Consider the sun, moon, and earth as shown in Figure 1. For each of the numbered positions of the moon, arrange your "moon," "sun," and yourself as earth. Observe carefully the illuminated surface that you, as earth, can see. Draw the illuminated area on the proper moon disk in the diagram. Shade the part of the disk that is NOT illuminated.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NAME______________________________________ SECTION__________ DATE__________

INVESTIGATION 33-2

The Path of the Moon in Space

Aim: To discover the path of the moon in space

Step A First let us consider the earth and the moon from the point of view of an observer on earth.

1. To an observer on earth, what is the apparent movement of the earth?

2. To an observer on earth, what is the apparent movement of the moon?

Step B Now consider the earth-moon pair from the point of view of an observer on the sun.

3. To an observer on the sun, what would be the apparent motion of the earth?

4. To an observer on the sun, what would be the apparent motion of the moon?

Step C Figure 1 shows a small part of the path of the earth in its orbit around the sun. The earth travels along the path from position I through position IX in 28 days. During that time the moon has made an apparent orbit around the earth. The point adjacent to each Roman numeral represents the earth, and the circle around it represents the orbit of the moon observed from the earth. There are eight uniformly spaced points on the circle that represents the moon's orbit. On the orbit that surrounds earth position I, these points are numbered 1 through 8. The moon moves from point 1 when the earth is at position I, to point 2 when the earth is at position II, and so forth. When the earth reaches position IX, the moon will have made a full apparent orbit around the earth. You will now plot the actual course of the moon as if it were observed from a point in space from which you could look perpendicularly at the plane of the earth's orbit around the sun.

5. On each of the lunar orbit circles, mark the position of the moon for that particular earth position on its orbit.

6. Connect the series of points that you have marked with either straight lines or a smooth curve, whichever is easiest for you.

7. Examine what you have drawn. How would you describe the path followed by the moon?

8. The sun is traveling in an orbit through the Milky Way in much the same way that the earth is traveling in an orbit around the sun. What do you suppose the path of the earth appears to be in space?

Teacher's Demonstration:

EFFECT OF O_2 ON PYRITES

To demonstrate the effect of oxygen on pyrites (a sulphide mineral) you need to demonstrate the following: (1) oxygen in dry air has little or no effect over a short time, (2) water with no air in it has a minimum effect over a short time, and (3) the combination of oxygen and water vapor does have an effect in a short time.

1. Powder a small amount of pyrites.

2. Place a pinch of the powdered pyrites on a piece of dry filter paper or a small piece of paper towel. Place this on a watch glass. Fill the lid of a mayonnaise jar with anhydrous calcium chloride, and put the watch glass and its contents on top. Place a ring of nondrying modeling clay around the base of the jar lid and invert a tumbler or jelly glass over the assembly. Press the rim of the glass into the clay to make a tight seal.

3. Place a pinch of the powdered pyrites in a test tube. Fill the test tube with *freshly boiled* distilled water. Stopper the tube with a rubber stopper. Dry the stopper and pour melted paraffin over it to seal it.

4. Place a pinch of powdered pyrites on a piece of moist filter paper or paper towel on a watch glass. Cover it with a jelly glass or tumbler. Add a drop or two of water each morning to keep the paper moist.

5. Set the experiments aside where they can be observed daily. In the first setup (No. 2 above) you have exposed the pyrites to dry air. The calcium chloride will reduce the water vapor in the trapped air to a negligible amount. In the second setup (No. 3 above) boiling the distilled water will remove the dissolved air and leave the pyrites exposed only to water. In the third (No. 4 above) you have exposed the pyrites to both water and oxygen.

After a few day—in some areas, a week—the pyrites in water will show a slight "weathering" from the action of the water. The powder may have a slightly rusty tinge. The pyrites exposed to water and air will have a great deal of rust, and the paper will be stained. The pyrites exposed to dry air will be unaffected. If you test the moist paper in the third setup with litmus, it will give an acid reaction, since sulphuric acid was formed. The water in the test tube for the second setup may or may not give an acid reaction.

Teacher's Demonstration:

LOADING ON THE CONTINENTAL SHELF

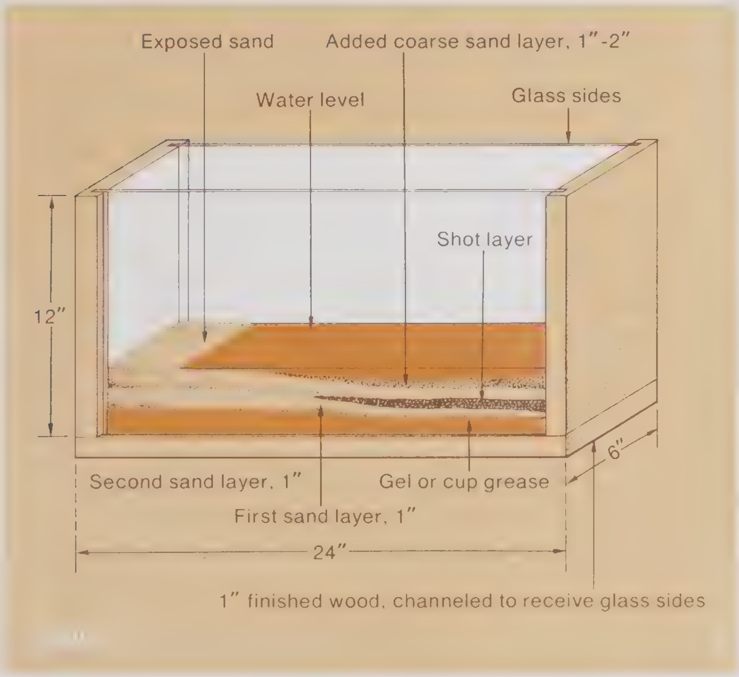
Aim

To simulate the effect of loading on the continental shelf

The apparatus for this demonstration can be built in any manual training shop from the working drawings supplied in Figures 1 and 2. The recommended dimensions may be changed within reasonable limits.

Preparation

Cover the bottom of the trough with gelatin made with half the recommended amount of water. A 2″ layer of light cup grease is desirable, but gelatin is cheaper and more easily obtained. Cover the layer of gelatin with plastic wrap so that the edge of this film comes up to the top of the sides and ends of the trough. Pour a layer of sand on top of the film, making the total contents about an inch thick. At the right-hand end, add about a pound of No. 1 shot, which can be purchased at a sporting goods store. Spread the shot on the bottom beginning at the end of the trough and extending for about 12″. Add a 1″ layer of sand on top. Build the sand layer thicker at the left end until you have a profile like the one shown in Figure 2. Gently add water to the trough until it reaches the level shown in the figure. Continue to add water as it percolates into the sand. It may take 15–20 minutes to saturate the sand. This preparation should be completed before making the demonstration.



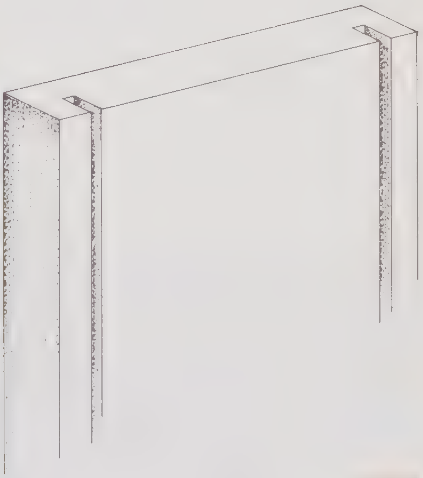


Figure 1

1″ x 6″ x 12″ finished pine (2 pieces)
1″ x 6″ x 24″ finished pine (1 piece)
23½″ x 12″ window glass (2 pieces)
Make ½″ deep rabbets to hold glass on top and bottom pieces. Cement the glass into the grooves with putty. Screw the end pieces firmly to the bottom.

Demonstration

First, explain to the class that the apparatus represents a model of the cross section of the edge of a continent. Some of the land and the continental shelf are apparent. Second, explain that you are going to try to demonstrate what happens as the continental shelf is loaded with sandy sediments. Point out that the gelatinous material at the bottom represents the plastic layer in the earth's crust. Explain that the loading of the continental shelf takes place slowly and that the model does not contain enough continent to supply the sediments.

Third, add about an inch depth of coarse sand to the continental shelf area of the model. Call attention to the slight depression of the plastic layer under the shelf. Add more coarse sand to the shelf. Call attention to further depression of the plastic layer under the shelf and the slight uplift as represented by the thickening of the plastic layer under the continent.

Fourth, point out that the action that has been simulated takes place in nature over millions of years, not in the few minutes that were devoted to the demonstration.

With a long-handled kitchen spoon, remove the sand that was added during the demonstration to restore the balance. You are then ready for the next class.

Teacher's Demonstration:

WAVE MOTION

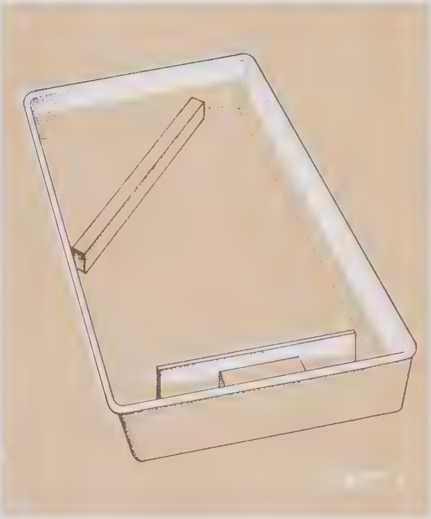
Preparation

Most physics departments now use a wave-generator and ripple tank originally designed for PSSC courses. You will find this device very useful in demonstrating what happens to waves as they meet various obstructions. The machine should be set up in such a manner that all pupils have a clear view of the ceiling above the ripple tank if illumination comes from below or so that they can gather around and watch the display if the light is above the tank.

The submerged barriers should be cast of paraffin and loaded with lead shot or nails while semimolten. The other barriers should be made of hardwood, 1″ x 2″ stock, cut to the proper lengths. They may be finished with spray-on varnish or enamel paint. They work best when the surfaces are as smooth as possible.

Models of particular shorelines can be fashioned of paraffin and placed at the far end of the tank for study of wave patterns.

The authors have found that the standard ripple tank (Hubbard 2401), while satisfactory, is a little small for complicated earth science demonstrations. For these, a tank 2 feet by 4 feet or even 6 feet is more satisfactory. It can be built in any school shop. Be sure that the glass used for the bottom is either very heavy windowpane or light plate glass.



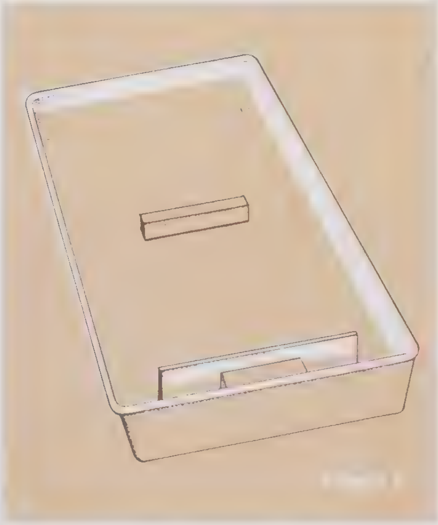
Demonstration

Simple reflection Operate the wave-generator at low speed and watch the wave front being thrown back or reflected as it meets the opposite end of the tank. The reflected waves may phase with the direct wave and reinforce the oncoming wave, or they may be wholly out of phase and essentially cancel the oncoming wave. This depends upon the velocity and wavelength of the generated waves, and can be controlled by varying the speed of the wave-generator.

Reflection at an angle Place a barrier at the side opposite the wave-generator and at 45° to the direction of wave travel, as shown in Figure 1. The reflected waves will move away from the barrier at 90° to the oncoming waves and will form a dappled interference pattern. A little chalk dust or talcum powder sprinkled on the surface of the water will show that a longshore current is set up.

Refraction Place a short barrier about midtank, with its long face parallel with the generated wave front, as shown in Figure 2. A concentric pattern of refracted waves will be seen rounding the ends of the barrier and disturbing the water surface that is shielded from direct waves.

Effect of wavelength on refraction Use the same setup and vary the frequency with which the waves are formed by speed-



ing or slowing the wave-generator. The high-frequency waves with short wavelengths will be refracted more than the waves with longer wavelengths.

Inlet effect Place two barriers across the midsection of the tank so that the outer ends are in contact with the outer walls of the tank and the inner ends are 2″ or 3″ apart. (See Figure 3.) Waves will be produced in the protected "lagoon" behind the barriers, and will spread throughout the protected area radiating from the inlet.

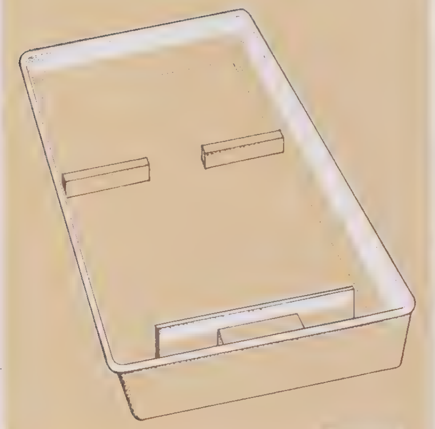


Figure 3

Focusing effect of a submerged ridge Place a wedge-shaped block such as that shown in Figure 5 at the end opposite the wave-generator, with the thin end of the wedge toward the generator and the thick end against the far wall. (See Figure 4.) This obstacle will refract the waves and they will be reinforced as they pass over the obstacle.

Shoaling water off a beach In the far end of the ripple tank, place a sloping board or piece of glass to represent shoaling water off a beach. Set this at an angle to the direction in which the waves travel. Use a low speed on the wave-generator. The incoming waves will refract and turn toward the "beach."

The only limit to the number of demonstrations possible with a wave-generator and ripple tank is the ingenuity of the demonstrator. The above seven cover the principal demonstrations needed to illustrate the text.

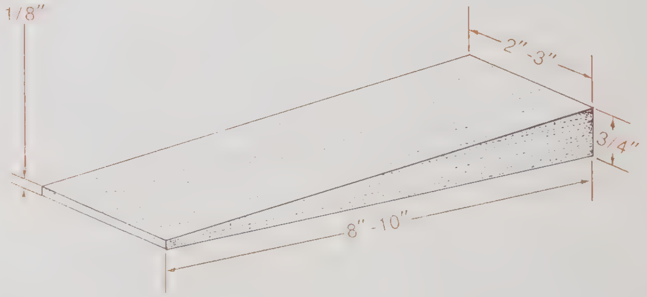


Figure 5

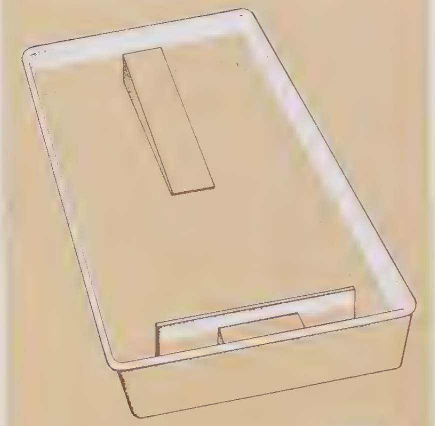


Figure 4

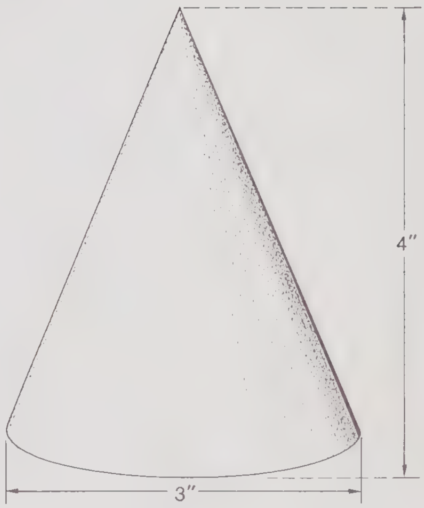
Teacher's Demonstration:

SIMULATING VOLCANO

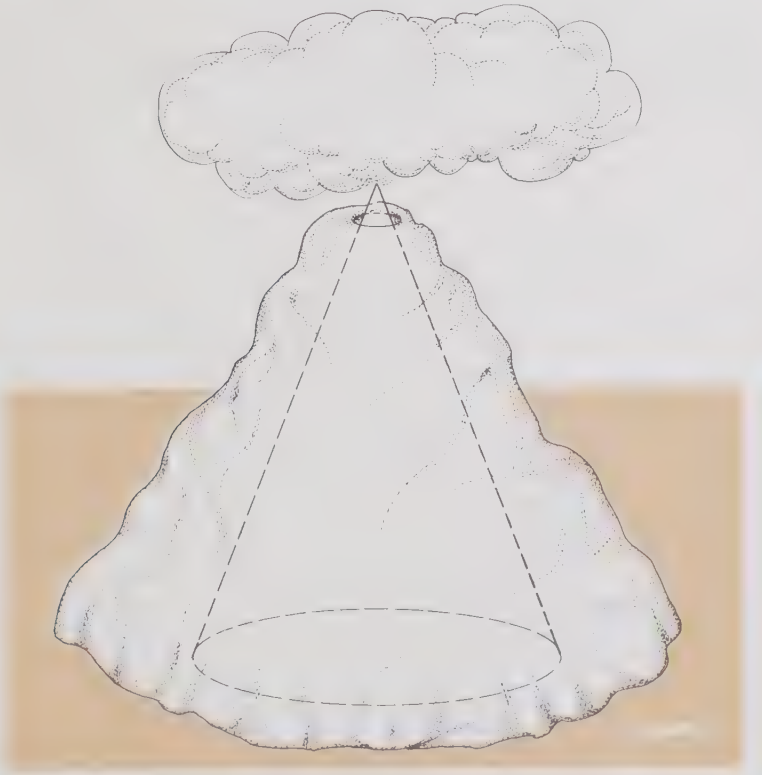
It is possible to produce a convincing minature volcano as a teacher demonstration. The effect is caused by burning ammonium dichromate. The reaction produces enough hot gases to eject the voluminous fluffy chromic oxide that is produced. The demonstration may be made simple or elaborate depending upon how much time you wish to devote to preparation. The simplest demonstration is to heap about 2 ounces (50-60 grams) ammonium dichromate on a thick asbestos sheet. Use a fuse of magnesium tape, about 2″ long, to ignite the dichromate. As it burns, it will throw up deep-green-colored chromic oxide ("scoria") and a few sparks. The "scoria" will fall back and build a cinder cone.

For a slightly more elaborate demonstration you can make a model in plaster of paris of a small volcano with a crater about 1″ in diameter and a cross section like that shown in Figure 1. Place the model on an asbestos sheet, and charge and fire it. A sand table with a 2″ layer of sand may be used instead of the asbestos sheet.

With a little ingenuity you can design such an elaborate demonstration that it will seem as if a crevasse appears in a "field" and a cinder cone similar to Parícutin will develop. The larger the charge, the longer the volcano will erupt. The charge of ammonium dichromate may be increased to as much as 8 ounces (250 grams.)



Make a cone of heavy manila-folder paper.



Coat the cone with thick plaster of paris in a layer ¾″–1″ thick. When dry (2–3 days), cut the tip off the paper cone. Charge and use.

Introduction To Reading And Interpreting Topographic Maps And Stereoscopic Aerial Photographs

The following four exercises have been selected from the Silver Burdett manuals *Topographic Maps for Earth Science* and *Stereoscopic Aerial Photographs for Earth Science*. These exercises were chosen for presentation here because they are representative samples and are an appropriate introduction for students who are not familiar with the reading and interpretation of such maps and photographs. Answers to the questions posed in these sample exercises may be found on page 169.

Information obtained from the correct interpretation of topographic maps and stereoscopic photographs is an integral part of the study of earth science. Therefore, these two exercise manuals, which give students practice in the skills of reading and interpreting maps and photographs, have been incorporated in the SILVER BURDETT EARTH SCIENCE PROGRAM. It is recommended that if time and student interest warrant, the whole of the two manuals be undertaken for study.

The exercises are certain to increase the students' understanding of and interest in the study of earth science. The maps and photographs cover a wide geographic range and include an extensive and interesting array of geologic formations. Procedural instructions are self-explanatory within each exercise.

27 DISSECTED DOME

AREA: LITTLE DOME, WYOMING

In the sparsely vegetated hills of the West, earth structures are often exposed in such detail as to look like a model. Such is Little Dome. Since this dome is elongated, the pattern of upended sediments dipping away from the center resembles a pitching anticline, as shown in Exercise 25. However, a dome is clearly formed by being pushed up from underneath. Once a dome has been stripped by erosion, it may show the core of a once-molten rock or even a column of salt that did the pushing.

A. The core rock at *A* does not seem to be exposed. The rock at the center looks much like the overlying sediments. Unless there is an erosion-resistant igneous core exposed, the hollowing-out of the center as shown here is typical. This hollowing may have resulted because weaker sediments have been exposed. In what other way could the layers at the center of the dome have been weakened by the push from below? They would have been stretched, and the tension cracks formed in them would speed the break down.

1. What do you think would be the rock types of the ridges and valleys here?

B. If material is to be carried away from (almost quarried out of) the center of the dome, there must be a well-formed drainage system to carry it.

2. What would have been the patterns of the first streams flowing off the dome?

As erosion progresses, the tributaries carve their channels into the weaker rock layers, gradually etching out a pattern of concentric circles of alternately weak and strong layers as at *B* and *B′*. This ringlike system is called an annular drainage pattern. A weak layer may develop a broad, flat, oval valley called a race track.

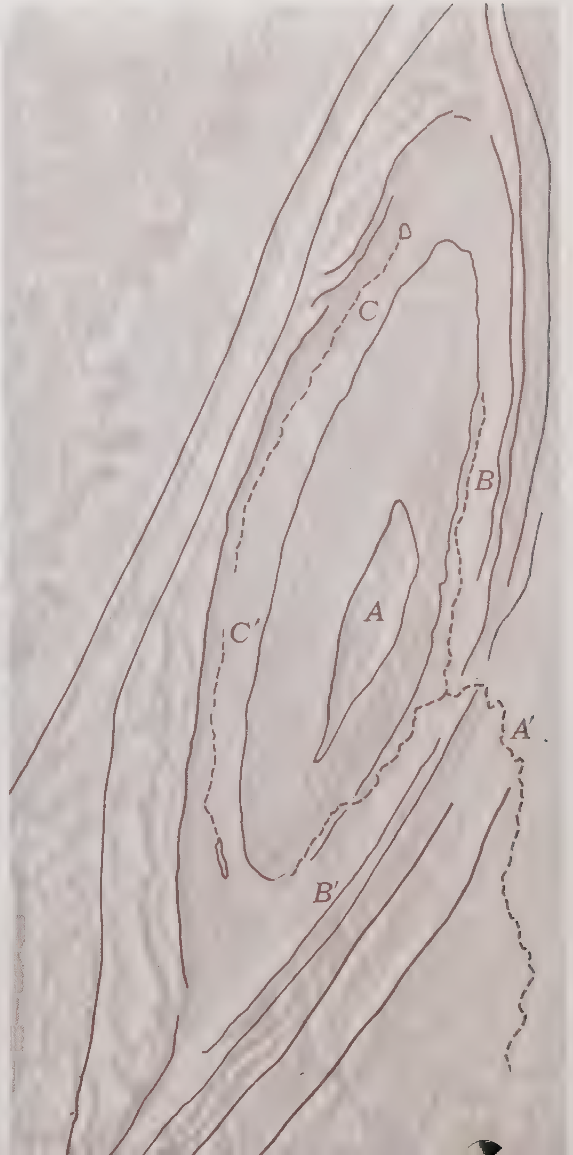
3. Where is the racetrack here?

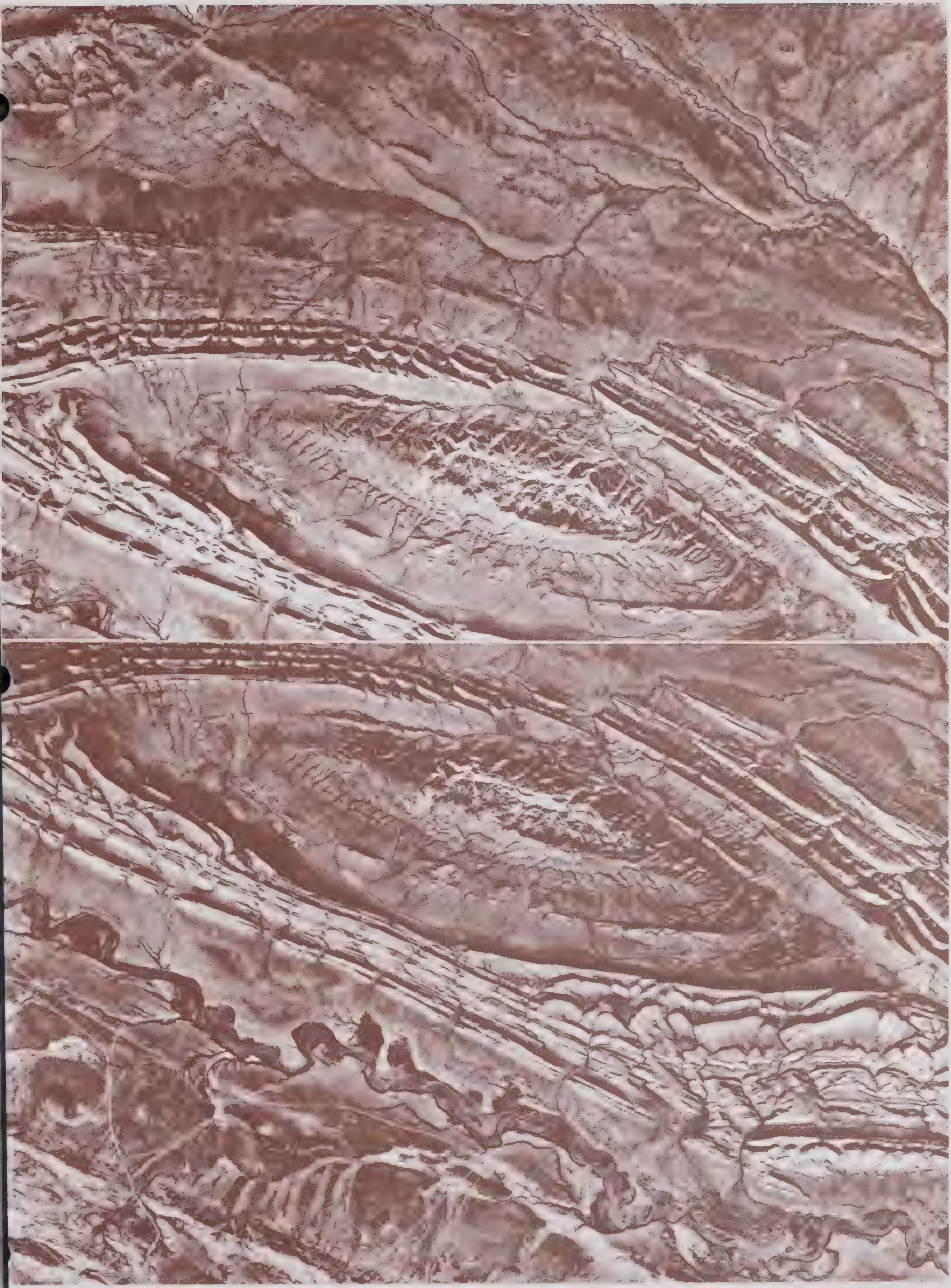
In time one or more of the original streams becomes the master stream, whose tributaries may almost encircle the whole dome.

4. Which is the master stream here?
5. Notice that the two streams flowing at the ends of the dome, *C* and *C′*, no longer drain the racetrack. Where do these streams drain?
6. What does interior drainage, as noted above, indicate about the climate?
7. What do the playas and the dammed-up pond near *A* indicate about the rock composing the racetrack?

Note that the smallest secondary streams have etched out triangular slabs in the tilted layers. These are called flatirons because of their shape. (See also Exercise 23.)

C. Exercise 25 described rock layers dipping into the ground. A geologist not only measures the angle at which layers dip into the ground, but he also maps the compass direction taken by the edge of an outcrop of rock. For example, the upended rock layers, or hogbacks, at *B* and *B′* dip down to the right, but their exposed edges run, or strike, from lower left to upper right. A geologist would map them, using a dip-and-strike symbol as marked on the diagrams, in which the arrow indicates the direction of the dip, and the straight line at right angles to it indicates the direction the edge of the outcrops runs, or strikes.





31 METEOR CRATERS ON THE MOON

AREA: GOCLENIUS CRATER, SEA OF FERTILITY

Our final stereoscopic aerial photographs were taken from Apollo 8 as it orbited the moon on the first round-trip flight, at the end of December 1968. Due to previous photomapping, Apollo 8 and following flights were furnished with detailed navigational charts of this unknown terrain. The chart produced from the Apollo 10 flight includes the predetermined flight path for Apollo 11, photographic data, checkpoints, and the location of an earlier Surveyor landing, as well as the proposed landing site of Apollo 11's Eagle in the Sea of Fertility.

A. Note that this pair of photographs was taken at an angle to the lunar surface rather than straight down. The low position of the sun (about 12 degrees above the lunar horizon) brings out the relief of the crater walls.

1. Would you say that the three craters left of center are older, or younger, than Goclenius? Why?
2. Since there is no atmosphere that would produce stream or wind erosion, what process might have softened the contours of Goclenius?
3. In what other exercise have you seen active slumping?
4. Would moonquakes hasten the slumping process?

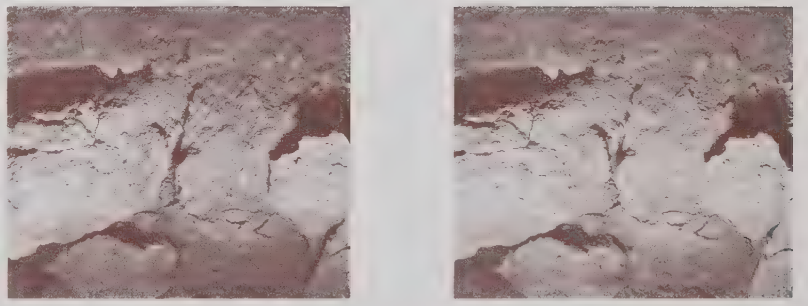
B. Examine the lines crossing Goclenius crater. Selenologists, scientists who study the moon, call these lines rilles. However, on Earth, rills are erosional features.

5. Why are lunar rilles probably not due to erosion?
6. What earth feature does the long rille across Goclenius most resemble? Why?
7. Would you say that the crater had been formed before, or after, the rilles? Why?
8. If the rilles are fault lines, what do they tell us about the "dead crust of the moon"?

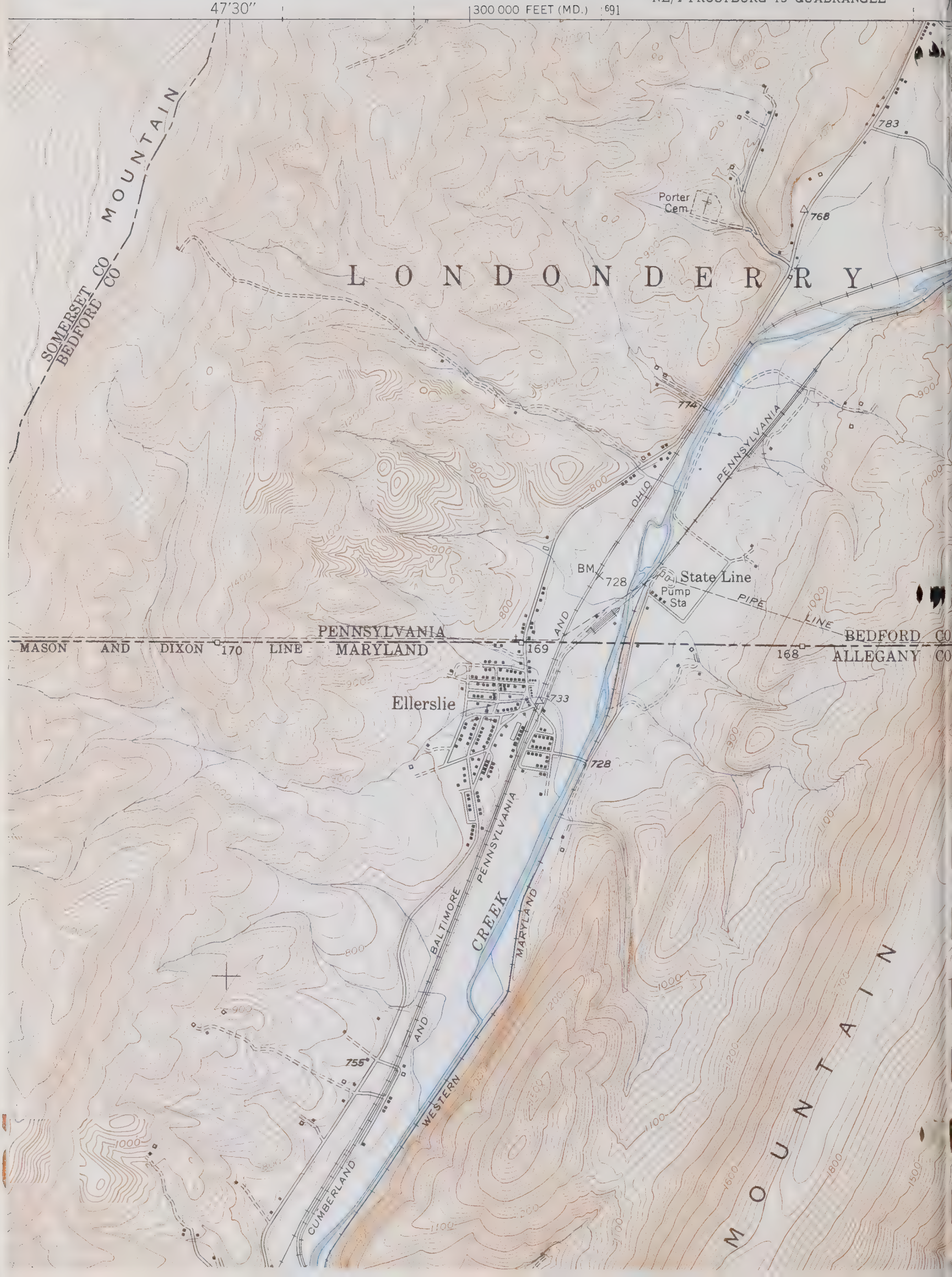
To help answer the above and other questions, the Apollo 11 astronauts left a seismometer on the moon to record moonquakes.

LUNAR ROCKS

A stereoscopic closeup view showing a clump of lunar surface material. Many small, shiny particles can be seen in this area of lunar surface that is three inches across. The exposure was made by the Apollo 11 35-mm stereo closeup camera. The camera is mounted on a walking stick, and the astronauts used it by holding it up against the object to be photographed and pulling the trigger on the walking stick.



CUMBERLAND QUADRANGLE
MARYLAND-PENNSYLVANIA-WEST VIRGIN
7.5 MINUTE SERIES (TOPOGRAPHIC)
NE/4 FROSTBURG 15' QUADRANGLE



Map: Cumberland, Md.–Pa.–W. Va.
Contour interval: 20 feet
Scale: 1:24,000 (1 in. = 2000 ft.)
Reference: 39°37′30″N, 78°52′30″W

MAP EXERCISE 1

READING A MAP

On the opposite page is the NE corner of a United States Geological Survey topographic map. The upper right corner shows the location of the area included on the entire map. On a U.S.G.S. map, information about who did the mapping and how it was done appears in the lower left corner of each sheet. The scale information is centered at the bottom. You will also find information about the relationship between magnetic (compass) north and true north at the bottom of the map. On U.S.G.S. maps, true north is always in the direction of the top of the sheet.

A. At the corners and along the border lines of the map you will find the geographic coordinates. The geographic coordinates in the SW corner of a map are the reference for the map.

1. What are the latitude and longitude of the NE corner of the map?
2. This quadrangle is 7.5 minutes square. What designation of longitude and latitude would you find in the SW corner?
3. Notice that there is a large black cross (**+**)in the lower left portion of the map. This marks the intersection of what lines of longitude and latitude?

B. The brown lines on the map are called contour lines. Each line connects all the points that are at the same elevation above sea level. Notice that each fifth line is heavier than the others. Also notice that on this map each of these heavier lines is labeled with a number that is an even multiple of 100.

4. What change in elevation does each of the finer lines indicate?

In the SE corner of the map, there is a narrow region where the contour lines are relatively far apart. On both sides of this region, and more or less parallel with it, the contour lines are closer together. Notice how the contour lines are numbered. This is the way a mountain ridge is represented by contour lines.

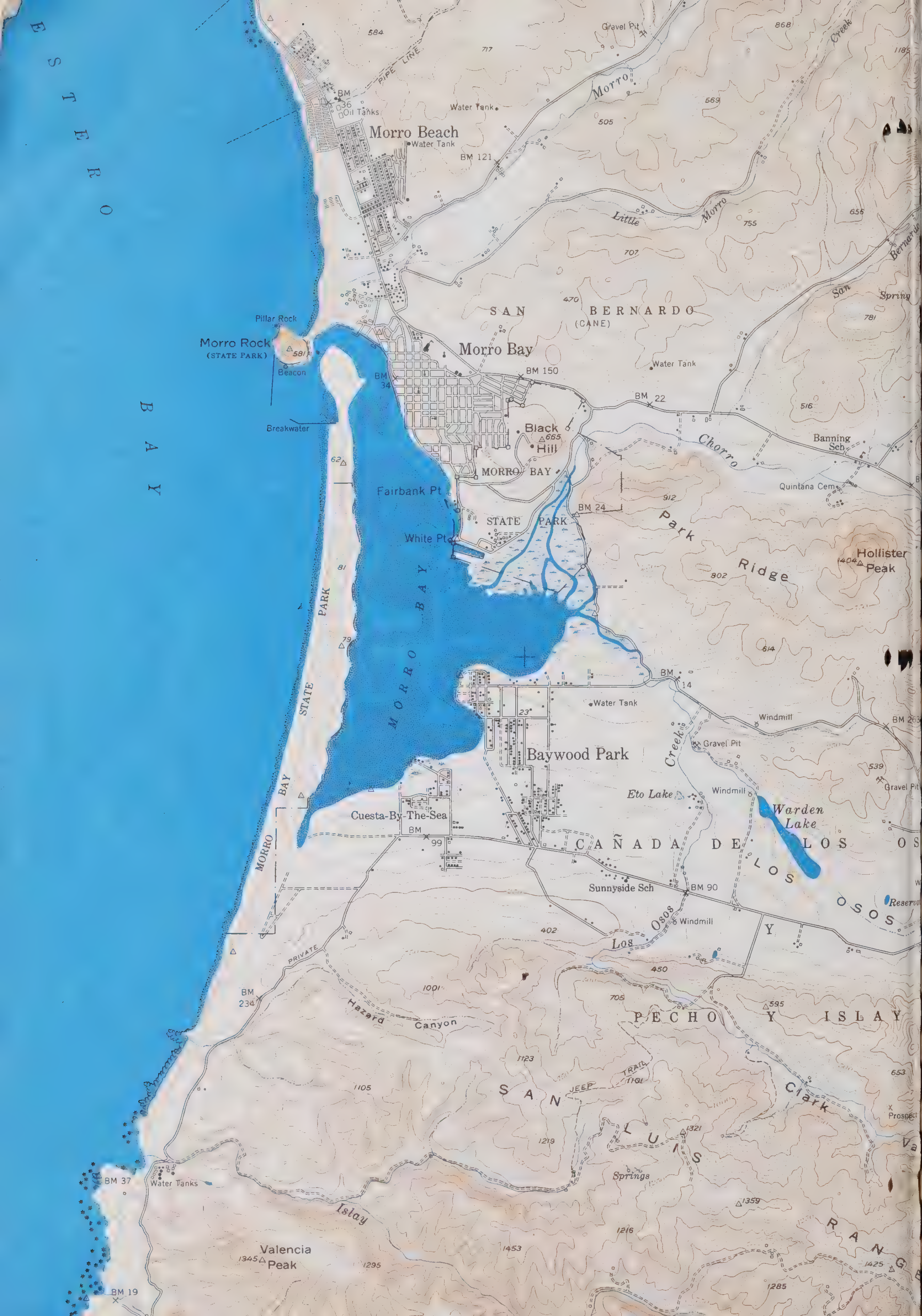
5. What is the elevation of the high point of this ridge?
6. What is the elevation of the valley around Ellerslie?
7. How high above the valley is the high point of the ridge?
8. Examine the contour lines on the west side of the ridge. Are they closer together above or below the 1200-foot contour line?
9. What does your answer to Item 8 suggest to you about the steepness of the slope?
10. Test your answer to Item 9 this way: Measure the distance between the 1200- and 1400-foot contour lines. It is 0.25 inch. The scale of the map is 1:24,000. How many feet does 0.25 inch represent?
11. By dividing the change in elevation (200 feet) by the number of hundred (5) horizontal feet, you arrive at the gradient per 100 feet. What is the gradient in the area measured in Item **10**?
12. Now determine the gradient per 100 feet between the 1000- and 1200-foot contour lines. What is it?
13. State a general rule that you can use to relate contour lines to the gradient of a slope.

C. In the NW part of the map, there is a house. It is high on the mountain and all alone. A road leads to this house.

14. How far in a direct line is this house from its nearest neighbor?
15. How high above its neighbor is this house?
16. What is the straight-line gradient between the two houses?
17. Most automobiles have difficulty climbing a rough, unpaved road with 12% grade of slope (12-foot climb per 100 feet). Would it be easy to drive to the house high on the mountain?

D. Measures of the gradient of land slopes usually are given in feet per 100 feet. Major streams usually have such low gradients that it is usual to state the gradient of a stream in feet per mile. Wills Creek is the stream that flows by Ellerslie. Close to the southern edge of the map you see a contour line that crosses Wills Creek. Follow the creek north until you find the next place a contour line crosses it.

18. How much has the stream changed in elevation between these contour lines?
19. What is the map distance along the creek between the lines?
20. What is the gradient per 100 feet?
21. What is an easy way to convert your answer for Item **20** to a per-mile gradient?
22. What is the per-mile gradient of the stream?


ESTERO BAY
Morro Beach
Water Tank
Oil Tanks
BM 36
BM 121
PIPE LINE
Gravel Pit
584
717
868
1185
Morro
Creek
Water Tank
569
505
Little
Morro
755
656
707
470
SAN BERNARDO
(CANE)
San
Bernardo
Spring
781
Pillar Rock
Morro Rock
(STATE PARK)
581
Beacon
Breakwater
Morro Bay
BM 34
BM 150
Water Tank
BM 22
516
Banning Sch
Black Hill
665
MORRO BAY
STATE PARK
Chorro
Quintana Cem
62
Fairbank Pt
White Pt
BM 24
912
Park Ridge
Hollister Peak
1404
802
81
MORRO BAY
STATE PARK
79
614
BM 14
Water Tank
Windmill
BM 263
23
Baywood Park
Creek
Gravel Pit
539
Gravel Pit
Eto Lake
Windmill
Warden Lake
Cuesta-By-The-Sea
BM 99
CAÑADA DE LOS OSOS
Sunnyside Sch
BM 90
Reservoir
MORRO BAY
Los Osos
Windmill
Y
402
450
PRIVATE
1001
705
595
BM 234
Hazard Canyon
PECHO Y ISLAY
1123
653
1105
JEEP TRAIL
1101
Clark
Prospect
SAN LUIS RANGE
1219
1321
Springs
BM 37
Water Tanks
Islay
1359
1216
Valencia Peak
1345
1453
1295
1425
1285
BM 19

Map: Cayucos, Calif.
Contour interval: 50 feet
Scale: 1:62,500 (1 in. = 5208 ft.)
Reference: 35°18′N, 120°52′W

MAP EXERCISE 4

MAKING AN OVERLAY

OFTEN WHEN you are working with maps you want to examine some particular relationship between features. Sometimes it is convenient to use an overlay for this. As you will see, the advantage of using an overlay is that you can eliminate all the details on the map except those you need for your study. Here is an example of the preparation of an overlay and one way that an overlay can be used. You may find overlays useful in other map exercises that do not call for them. There is nothing that says you must not make an overlay!

A. The scientists who are studying the great masses of ice in the polar regions state that if all of it melted, sea level would rise about 125 feet.

1. What effect would this have upon the country shown on the map?
2. What is the contour interval of this map?
3. Where would the new shoreline be?
4. Is there a 125-foot contour line marked on the map?
5. Where would you locate the approximate position of the 125-foot contour line?

B. The best way to get a good idea of the effect of a 125-foot rise in sea level is to prepare an overlay that shows only the present shoreline and the 125-foot contour line. Then all the area between the two represents land that would be submerged.

Place a piece of tracing paper over the map. Register this by marking three points on the paper with a sharp, soft pencil. Use BM 19 (bench mark 19) in the SW corner of the map, BM 36 near the oil tanks north of Morro Beach, and the triangulation point 1404 on the summit of Hollister Peak near the eastern margin of the map. This is done so that you can always place the overlay as you now have it, should the overlay slip while you are working on it.

Keeping your overlay registered, carefully trace the present shoreline. Be careful that you do not press so hard with your pencil that you make an impression on the map. Now you are ready to trace the future shoreline on your overlay. Be sure that your three register marks are over the points that they represent on the map. Carefully draw a line that lies about halfway between the 100-foot contour line and the 150-foot contour line. Again, take care that you do not press too hard with your pencil. Now remove your overlay from the map for the rest of the exercise.

C. Study your overlay and the map.

6. In which general area is there the least distance between the present shoreline and the future one?
7. In which area is there the greatest difference between the two shorelines?
8. What happens to the new shoreline at each stream?
9. What would happen to Morro Rock if the polar ice melted?
10. Would any new islands be formed if the polar ice melted?

D. The action of waves and currents in the past few thousand years (very recently in terms of geologic time) has moved sand along the coast. This action has tied Morro Rock to the land and built the beach that is now named Morro Bay State Park. In large part, the location of the barrier beach that cuts Morro Bay off from the ocean is determined by the headland of the San Luis Range.

11. Describe what we might expect to see in this region five or six thousand years after the new shoreline is established.
12. What do the sand bars in Morro Bay and the marshes in the eastern part of it suggest is happening there?
13. What would you expect to happen to Morro Bay after the new shoreline is established?
14. Predict what kind of shoreline will eventually be established.

EXERCISE ANSWERS

TOPOGRAPHIC MAP EXERCISE 1

1. 78°45′W and 39°45′N. **2.** 78°52′30″W and 39°37′30″N. **3.** 78°47′30″W and 39°42′30″N. **4.** 20-foot change in elevation. **5.** About 1900 ft. **6.** About 730 ft. **7.** 1900 − 730 = 1170 ft. **8.** Above the 1200-foot contour line. **9.** The slope is steeper above 1200 ft. than below it. **10.** 1 in. = 24,000 in. = 2000 ft. Therefore, 0.25 in. = 500 ft. **11.** 40 ft. per 100 ft. **12.** The gradient will measure 18 to 28 ft. per 100 ft., depending upon where it is measured. **13.** The closer together the contour lines, the steeper the slope. **14.** 4550 ft. **15.** 1700 − 970 = 730 ft. **16.** 730/45.5 = 16 ft. per 100 ft. **17.** No, the grade is steeper than 12% and the road is unpaved and probably rough. **18.** 20 ft. **19.** About 6.9 in. **20.** 0.146 to 0.143, depending upon the distance measured on the map. **21.** Multiply by 52.8, the number of 100-foot units in a mile. **22.** 7.8 to 7.5 ft. per mile.

TOPOGRAPHIC MAP EXERCISE 4

1. Part of the land would become ocean bottom. **2.** 50 ft. **3.** The new shoreline would be where the 125-foot contour line now is. **4.** No. **5.** Halfway between the 100- and the 150-foot contour lines. **6.** In the SW portion. **7.** Around Morro Bay and especially in Canada de los Osos. **8.** It extends farther inland along streams then elsewhere. **9.** It would become an island. **10.** In addition to Morro Rock becoming an island, a small island would be formed just east of the Gravel Pit that is east of Baywood Park, and there may be a tiny islet SW of Hill 802 of Park Ridge. **11.** The waves and current probably would build a new barrier beach about where the present one is or a little more inland, and possibly Morro Rock would again be tied to the land. **12.** Alluvium from the streams is filling in Morro Bay. **13.** The drowned stream valleys would fill with marshes, and in time the bay too would be filled and disappear. **14.** A smoothly curved shoreline similar to the one that now exists.

STEREOSCOPIC AERIAL PHOTOGRAPHIC EXERCISE 27

1. Probably resistant sandstone ridges, or possibly limestone in this dry climate; weak shale in the valleys. **2.** Radial, or away from the high center. In an elongated dome one could expect four streams. **3.** The second main ring from center, with streams *B-B′* and *C-C′*. **4.** The one at right, *A-A′*. **5.** Into two small playa lakes, one near each end. **6.** It is dry. **7.** It is probably shale, since it appears to hold water.

STEREOSCOPIC AERIAL PHOTOGRAPHIC EXERCISE 31

1. The craters are younger because they are more clear-cut and therefore fresher. The walls of Goclenius appear more worn down. **2.** Mass wasting, or slumping, due to gravity. **3.** In Exercise 24 (Surface Effects of Faulting). **4.** Yes. **5.** They are not due to erosion because they do not appear to drain a slope. Also, the long rille crosses over the rim of the crater. **6.** It resembles a fault line because it is straight and crosses the rim of the crater. **7.** It had been formed before the fault appeared because the crater explosion would have erased the line if it had occurred afterward. **8.** If the rilles are fault lines, it means that the lunar crust is active.

Laboratory Investigations in

EARTH SCIENC

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